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FM 30-10

DEPARTMENT OF THE ARMY FIELD MANUAL

TERRAIN INTELLIGENCE



HEADQUARTERS, DEPARTMENT OF THE ARMY
OCTOBER 1959

FIELD MANUAL

No. 30-10

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TERRAIN INTELLIGENCE

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PART ONE
NATURE OF TERRAIN INTELLIGENCE
CHAPTER 1
GENERAL

1. Purpose

This manual explains how terrain intelligence is produced. It is designed as a reference and training text for all personnel engaged in the production of terrain studies. This manual also serves as a guide for commanders and their staffs in understanding the purpose, scope, capabilities, limitations, and applications of terrain analysis.

2. Scope

This manual serves as a specific guide in all phases of the production and use of terrain intelligence. It defines terrain intelligence and explains the intelligence process of collection, evaluation, interpretation of information, and dissemination of the finished intelligence as this procedure applies to the terrain. It explains the relationship of the terrain study, produced by the engineer, to the terrain estimate, derived from it by Assistant Chief of Staff, Intelligence, (G2). Sources of information are discussed, including their relative value and the manner of their exploitation. Detailed instruction is given on the description of terrain features and on the analysis of individual features and overall terrain in terms of their military characteristics. Guidance is furnished on current doctrine for the preparation of the terrain study and its component parts, such as the cross-country movement map. The material presented herein is applicable without modification to both nuclear and nonnuclear warfare.

3. Relation to Other Manuals

The material presented in this manual is closely related to FM 5-30, FM 30-5, and TM 5-545. Other manuals of the FM 30-series cover specialized intelligence activities. FM's 100-5, 100-15, and 101-5 cover intelligence in general staff activities and in the plans and operations of large units. Manuals of the 5-series contain detailed information concerning the operation of engineer troop units and their intelligence agencies.

CHAPTER 2

INTRODUCTION TO TERRAIN INTELLIGENCE

Section I. NATURE OF TERRAIN INTELLIGENCE

4. Definitions

a. Terrain is an area considered as to its extent, and manmade and natural features in relation to its use for military operations.

b. Terrain intelligence is processed information on the militarily significant natural and manmade characteristics of an area.

c. Terrain analysis is the process of interpreting a geographical area to determine the effect of the natural and manmade features on military operations. This includes the influence of weather and climate on those features.

d. A terrain study is an intelligence product which presents an analysis and interpretation of the natural and manmade features of an area and their effects on military operations, and the effects of weather and climate on these features.

e. A terrain estimate is that portion of an analysis of the area of operations which concerns the description of the terrain, the military aspects of the terrain, and the effects of the characteristics of terrain on enemy and friendly courses of action, including their influence on the response to nuclear weapon effects.

5. Purpose of Terrain Intelligence

a. The purpose of all intelligence is to obtain data about the enemy, terrain, weather, and climate, thereby assisting the commander in making sound decisions and the troops in executing their missions. Terrain intelligence tends to remove uncertainties regarding the effects of climate, weather, and terrain upon a contemplated operation. In planning an operation, the commander and his staff analyze the effects that the terrain and weather conditions will have upon the activities of both friendly and enemy forces.

b. The commander must make the most effective use of the terrain assigned to his unit. If he is furnished with adequate terrain intelligence, he will be able to exploit the advantages of the terrain and avoid or minimize its unfavorable aspects. By the proper employment of terrain, a numerically inferior force may achieve combat superiority over a larger enemy force.

c. The compilation of terrain intelligence is not limited to enemy areas. It also covers the area occupied by the friendly force and the terrain to the rear and on the flanks.

6. Scope of Terrain Intelligence

a. Terrain intelligence is classified according to the mission and level of the command at which it is used. While these categories at time may overlap, they are considered broadly as *strategic* and *combat*.

b. Strategic terrain intelligence is concerned with the requirements of large-scale plans and may include intelligence concerning the military capabilities and vulnerabilities of entire nations. It is the intelligence produced for major agencies of the Department of Defense. Strategic intelligence is produced continuously and requires the compilation and interpretation of detailed information by highly specialized personnel. Included in strategic terrain studies are descriptions and analyses of beaches, water terminals, rivers, towns, and major terrain features; transportation and communication systems; and cross-country movement conditions, soils, rock types, underground installations, climate and weather, vegetation, state of ground and hydrography. The principal compilation of these studies is the National Intelligence Survey (NIS). Upon the outbreak of hostilities, such studies provide field commanders with their initial intelligence concerning the area of operations.

c. Combat terrain intelligence is produced for use in planning and conducting tactical operations. It is based upon information secured locally or provided by higher headquarters and is concerned primarily with the effects of weather and terrain upon the particular operations of the unit.

d. The difference in the type of terrain intelligence required by strategic planners reflects their objectives. The strategic planner may consider an entire country or continent, while the tactical planner is concerned only with the terrain in the area of his operations. Where the strategic planner often studies problems that may arise some years ahead and applies terrain intelligence in a wide variety of hypothetical tactical situations, the tactical planner is concerned only with problems that currently involve his unit or that may be anticipated in the near future.

7. Relation to Other Intelligence

Terrain intelligence is one element in the intelligence requirements of a commander. The engineer has a particular interest in terrain intelligence, since he is trained and equipped to make related terrain studies and to conduct field reconnaissance.

8. Applications of Terrain Intelligence

a. Terrain intelligence is essential for strategic and combat planning and for the conduct of operations.

b. Detailed and reliable terrain intelligence is required for all logistical plans, particularly those prepared for special operations or for operations to be conducted under extremes of climate. Special studies, prepared from a logistical viewpoint, are essential in planning operations in mountains, jungles, or deserts; in snow and extreme cold; and for airborne and amphibious operations.

c. All research and development agencies are concerned with the problems resulting from adverse climate, weather and terrain. Detailed and accurate terrain intelligence is necessary to determine the requirements for new means of transportation, types of shelter and construction, weapons, and clothing. It is a basic requirement in developing new equipment and in the maintenance and modification of existing equipment.

d. Current and accurate terrain intelligence is required by topographic engineer agencies for use in preparing or revising military maps.

Section II. RESPONSIBILITIES FOR TERRAIN INTELLIGENCE

9. Responsibilities

The Assistant Chief of Staff for Intelligence, Department of the Army, is responsible for procuring and assimilating terrain intelligence concerning all countries of the world. Responsibility for producing this terrain intelligence has been assigned to the Chief of Engineers. For functions of the agencies that assist in preparation of these studies see FM 5-30.

10. Command Responsibilities

a. Commanders at all levels are responsible for the production of intelligence, including terrain intelligence. A commander must—

- (1) Insure that he and his staff officers are always aware of the terrain situation and of the effects that weather and terrain will have upon their missions.
- (2) Know and utilize the capabilities for producing terrain intelligence that exist within his command or in outside agencies.
- (3) Insure that his command, within the limits of its capabilities, gathers all pertinent information on the weather and terrain, and that this information is transmitted to all other units requiring it.

- (4) Insure that the members of his command are trained in the basic skills of terrain analysis which are essential to the proper performance of their duties.

b. At theater level, strategic terrain intelligence is more detailed than the strategic intelligence compiled at Department of the Army level, and the production of this intelligence may be assigned to a unit formed for that sole function. At field army and lower levels, combat terrain intelligence is the principal concern, becoming increasingly detailed and localized at successively subordinate levels.

11. Responsibilities of Intelligence Officers

a. The terrain intelligence that a commander needs to make a sound decision and an effective plan must be provided by the unit intelligence officer. As a part of his intelligence report, the intelligence officer makes an analysis of area of operations. Normally he bases this upon a terrain study produced by the engineer.

b. The intelligence officer must plan and coordinate the collection of terrain information and the production, maintenance, and dissemination of terrain intelligence. Concurrently, he should keep the staff engineer informed of the advance planning that is in progress or in prospect, so that the engineer can secure and compile the required terrain information.

12. Staff Engineer Responsibilities

Under the general staff supervision of G2, the staff engineer—

a. Produces and maintains terrain studies based upon terrain analyses. This involves—

- (1) Determining the requirements for terrain information, based upon requests from G2.
- (2) Collecting and evaluating terrain information.
- (3) Assembling terrain intelligence into a terrain study.

b. Provides technical interpretation of the terrain covering such factors of military significance as obstacles, routes, and avenues of approach, cover and concealment, landforms, hydrology, cross-country movement, and related subjects.

c. Disseminates terrain studies and other technically evaluated information through appropriate channels.

CHAPTER 3

PRODUCTION OF TERRAIN INTELLIGENCE

Section I. INTELLIGENCE CYCLE

13. General

The intelligence cycle described in FM 30-5 is also followed in the production of terrain intelligence. This is accomplished by the following steps—

- a.* Collection of information.
- b.* Processing of the collected information.
- c.* Use of the resulting intelligence.
- d.* Direction of the collection effort.

14. Collection

a. Collection is the systematic exploitation of sources of information and the reporting of the information thus obtained to the proper intelligence agencies. A *source* is the person, thing, or activity from which information is obtained. An *agency* is any individual or organization which collects or processes information.

b. Sources of terrain information and collection agencies are discussed in paragraphs 18 through 23.

15. Processing

a. *Processing* is the step in the intelligence cycle whereby information becomes intelligence. It consists of three operations—recording, evaluation, and interpretation. These are explained in FM 30-5.

b. *Recording* involves the reduction of information to writing or other graphical form of presentation and the grouping of related items to facilitate study and comparison.

c. *Evaluation* is the appraisal of an item of information to determine its pertinence, the reliability of the source or agency, and the accuracy of the information.

d. *Interpretation* is the process of determining the significance of evaluated information with respect to information or intelligence already at hand.

16. Dissemination

a. *Dissemination* of intelligence is its timely transmission to all interested units and agencies.

b. Terrain intelligence is disseminated to commanders and staffs as one element of the overall intelligence report. Dissemination may be accomplished by means of briefings, conferences, messages, or such intelligence documents as the estimate, summary, periodic report, an analysis of area of operations, annex, maps, photointerpretation reports, and climatic summaries. Detailed information on the various intelligence documents is contained in FM 30-5.

17. Direction

a. The collection of terrain intelligence is directed by the responsible intelligence officer in the name of the commander. This direction involves—

- (1) Determination of intelligence requirements.
- (2) Preparation of a collection plan.
- (3) Issuance of orders and requests to appropriate collection agencies.
- (4) Continuous check on the production activities of the collection agencies.

b. Five successive steps are involved in direction—

- (1) Determination of the essential elements of information (EEI).
- (2) Analysis of the EEI to determine indications that would answer the questions presented in the EEI.
- (3) Translation of these indications into orders and requests for information pertaining to specific activities localities, characteristics, or conditions.
- (4) Selection of collection agencies to be employed and issuance of the necessary orders and requests for information.
- (5) Followup.

c. Detailed information about the direction of the intelligence effort is contained in FM 30-5.

Section II. SOURCES AND AGENCIES

18. Maps and Terrain Models




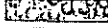
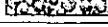
a. General.

- (1) Maps are a basic source of terrain information. They are intelligence documents, not supply items. Accordingly, the intelligence officer is responsible for staff supervision over military maps and survey activities. Procurement, storage, and distribution of maps are handled by the engineer under the supervision of the intelligence officer.
- (2) The classification of U.S. Maps by type and scale is described in FM 101-10. Foreign maps, or those copied from maps that were prepared by foreign agencies, are subject to many

CROSS-COUNTRY MOVEMENT

This map shows intelligence on cross-country (off-road) movement generalized to correspond with the scale of the map. Evaluations different from those indicated hereon may occur in areas too small to delineate. Hence, this map does not preclude necessity for reconnaissance and other detailed intelligence for tactical operations. Evaluations are for the M-48 tanks now in use by American troops. The use of special vehicles or methods is not considered in the evaluations.

EXPLANATION (Back of map contains more detail)

CODE	General Soil-slope Evaluations	
	Dry Period <u>1/</u>	Wet Period <u>2/</u>
B ₂ 	Passable	Doubtful to impassable
C ₁ , C ₂ 	Passable	Impassable
D ₁ 	Doubtful to impassable	Impassable
D ₂ 	Impassable	Impassable
	Dense Tree Growth	

Passable—Soil-slope conditions will support 40 or more M-48 tanks in trace or permit maneuvering of an M-48 tank.

Doubtful—Soil-slope conditions make movement of an M-48 tank doubtful; may support a few tanks in trace, but probably will not permit maneuvering.

Impassable—Soil-slope conditions will not support one pass or maneuvering of an M-48 tank.

EXPLANATION OF DRY AND WET PERIODS

1/ Dry period is the period when climatic factors combine to produce soil moisture contents that are generally low. The period occurs from about 1 May to 1 November—roughly, the growing season. Dry periods may occur at other times of the year as a result of long spells of fair weather.

2/ Wet period is the period when climatic factors combine to produce soil moisture contents that are close to or at the maximum. The period extends from about 1 November to 1 May. Wet periods may occasionally occur in other seasons of the year as a result of unusually heavy or long-enduring rains, floods, or irrigations, but drying of soil thereafter will be rapid.

EXPLANATION OF LETTER-NUMBER SYMBOLS

(Back of map contains more detail)

B₂ Usually moderately sloping areas surrounding the A₂ areas on Okefenokee terrace and the crests and top slopes of low flat hills and swales on Wicomico and Penholoway terraces. The soils are silty sands with more silt than A₂ soils, with organic material in the top few inches. No concretions.

C₁ Usually moderate or slight slopes fringing drainageways on Okefenokee terrace and relatively level to gentle slopes on the Wicomico and Penholoway terraces. Soils on the Okefenokee terrace are silty and clayey sands with high organic content in heavily vegetated areas; silty and poorly graded sands with appreciable amounts of organic matter occur on Wicomico and Penholoway terraces.

C₂ Gentle slopes surrounding drainageways on Okefenokee terrace and relatively level areas on Wicomico and Penholoway terraces. Soils are usually organic silty sands or poorly graded organic sands.

D₁ Slightly sloping areas adjacent to streams on Okefenokee terrace and the swamps on Wicomico and Penholoway terraces. Soils are silty sands, organic sandy silts and organic silts.

D₂ Low-lying areas consisting of the lowest portion of drainageways on Okefenokee terrace and large swamps on Wicomico and Penholoway terraces. Soils are organic silts, organic silty sands, and some clays with appreciable amounts of organic matter.

Figure 1. Portion of a trafficability map (vicinity of Camp Stewart, Georgia).

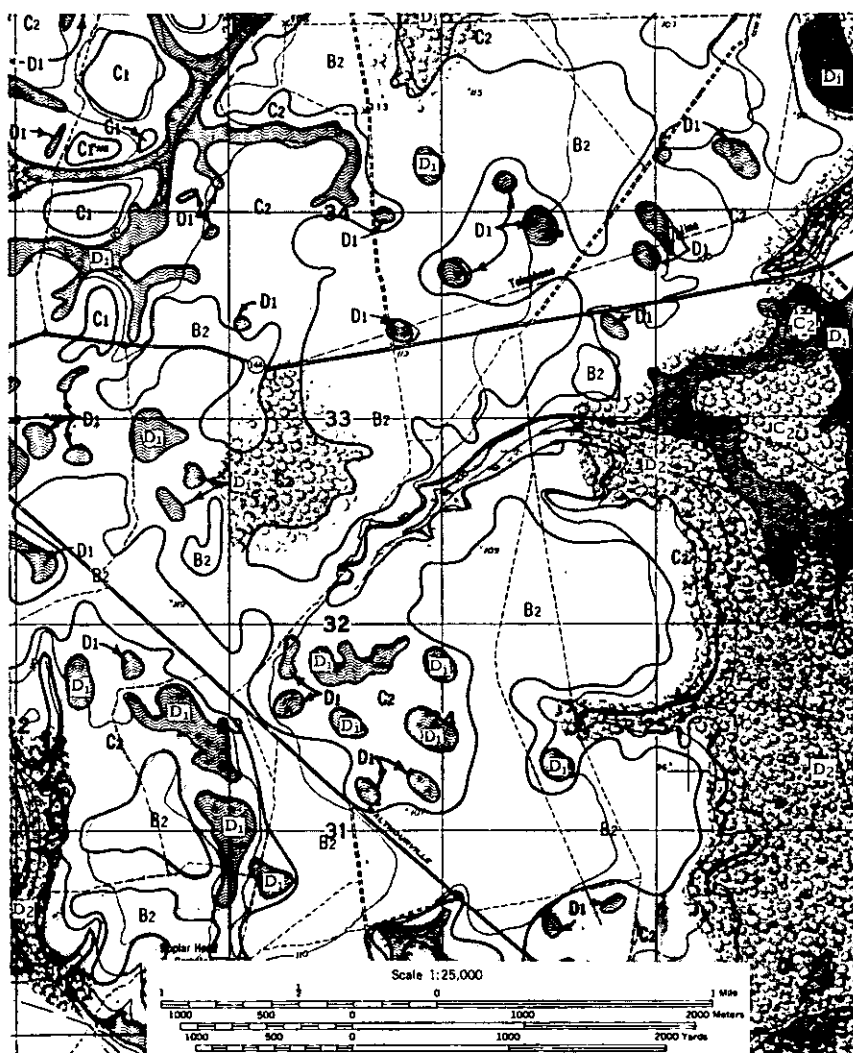


Figure 1—Continued.

variations from U.S. standards and procedures. Information about the maps and mapping practices of other nations is contained in TM 5-248.

- (3) Maps are reliable only to the extent indicated by the marginal data. Portions of one map sheet may be fully reliable and yet other parts of the same sheet may be based on data long out of date and therefore unreliable. The use of a map must be tempered by an estimate of the probable changes in manmade features that have occurred since the date of the original survey. All personnel must be impressed with the importance of reporting errors, changes, and omissions in existing maps, so that new editions may incorporate the necessary corrections.
- (4) Maps prepared for a special purpose may be reliable for information that does not pertain to that purpose. A railway map, for example, may be quite accurate in presenting railway information, but may be unreliable for data shown on roads or other features.

b. Special Maps and Overlays. Map and overlays may be prepared for specific military purpose or to show only particular characteristics of the terrain.

- (1) *Soil maps* are prepared primarily for agricultural purpose to show the potentialities of the soil for crop production. This type of map shows soils of various types, indicating their degree of acidity, nutrients, suitability for certain crops, and similar information. *Engineering soil maps* (fig. 1) indicate the qualities of soil from the viewpoint of construction or vehicle movement. Agricultural soil maps may be used for engineering purposes after they have been interpreted according to engineering nomenclature and requirements. *Vegetation maps* may be used to determine the general type of soil and depth of water table of an area.
- (2) *Geologic sketch maps* (fig. 2) show the geology of an area. *Outcrop maps* show the bedrock that is exposed. *Bedrock maps* show the surface of the bedrock as it would appear if the overlying soils were removed. These maps are useful in locating sites for major structures and in finding sources of rock for construction purposes.
- (3) *Communication maps* include those that show the system of lines and sequence of stations of railways, provide automobile route information, and indicate navigable waterways and the routes and stops of airlines.
- (4) Other special maps show the distribution of major vegetation types and show depth for use in mountain and winter operations; water supply sources and distribution system;

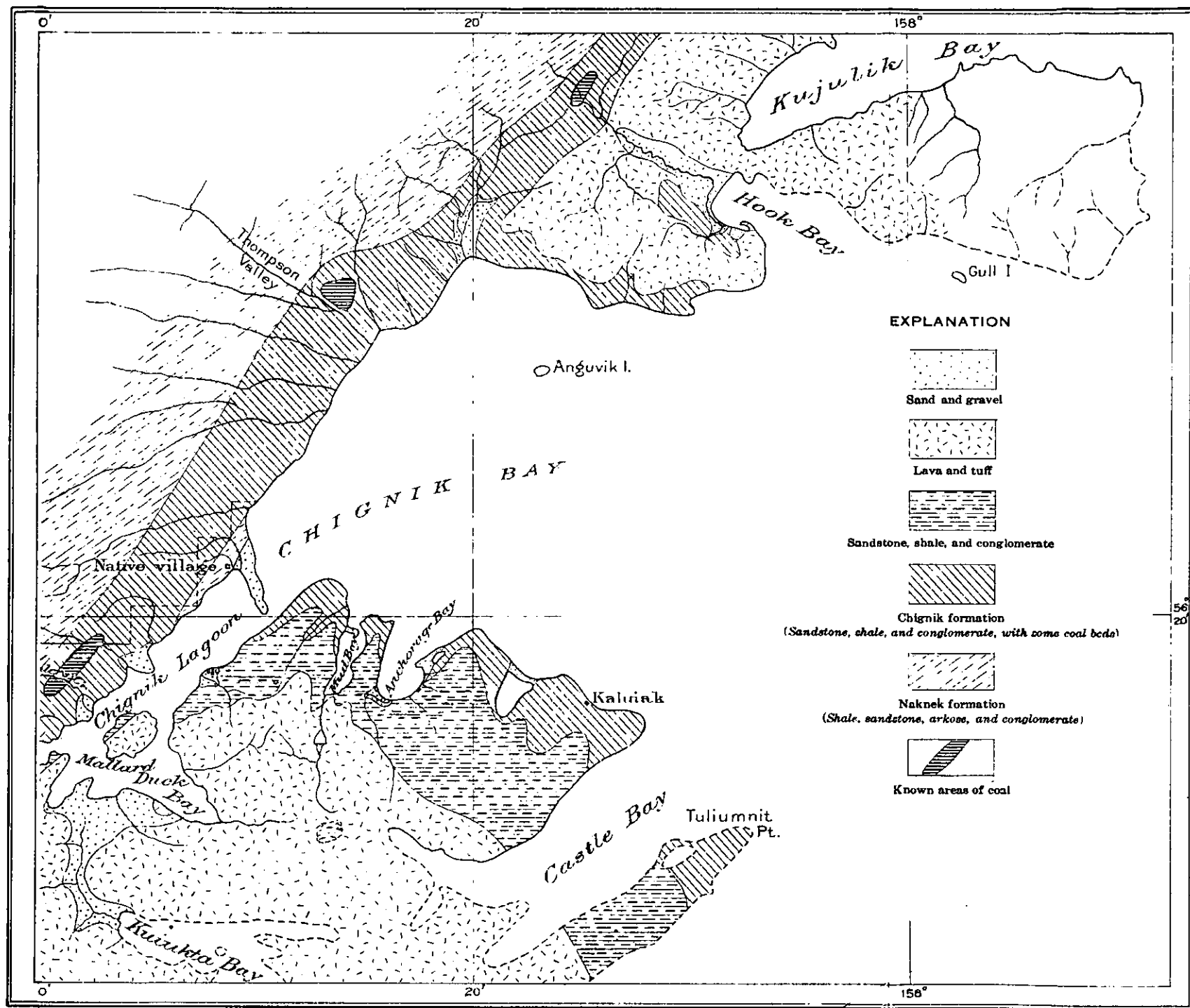


Figure 2. Portion of a geologic sketch map (Chignik district, Alaskan peninsula).

town and city plans; conditions affecting cross-country movement, and similar detailed information that can be presented most effectively in graphic form.

- (5) *Relief maps* show differences in elevation by the use of various tints and shading patterns. A molded plastic relief map is a standard topographic map printed on a plastic base which is formed to produce a vertical relief, with the contour lines shown at an exaggerated scale.

c. Terrain Models. A terrain model is a three-dimensional graphic representation of an area showing the conformation of the ground to scale. Usually it is colored to emphasize various physical features, and the vertical scale is exaggerated to convey relief. Terrain models may be made for use in strategic or tactical planning, assault landings, airborne landings, and aerial target delineation.

19. Photographs

a. General. Aerial and ground photographs provide a visual record of the terrain that is accurate. They furnish information that is not readily available by ground reconnaissance or by visual observation from the air, particularly concerning areas held by the enemy. A photograph preserves information in a permanent form, so that it is available for later study and comparison.

b. Advantages. Properly interpreted, aerial and ground photographs furnish information concerning—

- (1) The identification of vegetation, soils and rocks in broad classifications (fig. 3).
- (2) Both surface and internal drainage characteristics. Indications of surface drainage can be located, marked, and evaluated through detailed stereo study. In some cases, internal drainage can be predicted in general terms, such as "well-drained" or "poorly drained."
- (3) Suitability of terrain for airfields, roads, and underground installations, based upon topography, drainage, soils, and engineering materials. General characteristics can be given, such as "flat plain, predominantly fine-grained soils, well-drained, forest cover, deposits of gravel suitable for borrow."
- (4) Suitability of terrain for cross-country movement and airborne operations. Photographs and photomaps can be used advantageously in studying and rating areas as to their suitability for movement, based on the evaluation of relief, slopes, drainage, soils, and vegetation. General characteristics may be determined, such as "flat plain, grass-covered, silty soils, hedgerows, steep slopes, poor drainage."
- (5) Manmade features. Aerial and ground photographs, interpreted by skilled personnel, can give highly detailed infor-



Figure 3. Air photo with major soil characteristics superimposed.

mation about all types of manmade features, from artificial obstacles to large industrial complexes.

c. Limitations.

- (1) The interpretation of photography is limited by adverse weather and by jungles or other heavily wooded terrain.

- (2) Photographs will not provide detailed factual information concerning the engineering properties of soil, vehicle type and trafficability relationships, and quantitative data for materials and other items. This type of information usually can be obtained only through field sampling and laboratory testing procedures or by comparison with information from reconnaissance reports, geological surveys, and similar sources.

d. Requirements for Terrain Analysis.

- (1) There should be sufficient aerial photograph coverage made to enable the interpreter to determine the extent of local conditions and the expected variations. Usually vertical coverage is best, although oblique photographs may be useful for certain purposes, such as in the study of dense forest areas. Scales of from 1:5,000 to 1:20,000 are desirable for terrain analysis. Photographs in this range provide good area coverage per point and stereoscopic perception of relief. They show the general area relationships, such details as major gully characteristics, and the outstanding terrain features.
- (2) Photographs with scales between 1:30,000 and 1:60,000 or less provide excellent area coverage in the broadest sense. Major physiographic details are easily seen, studied, and bounded. Relief must be great, however, before stereovision is practical. Only major relief forms are clearly differentiated at these scales, and small details are lost. Major gullies can be plotted, for example, but in some cases their characteristics cannot be determined. As a rule, landforms can be delineated only when there is a great contrast in pattern. Slopes associated with landforms at times cannot be seen or distinguished. While such manmade features as roads, railroads, bridges, and buildings can be identified, the interpreter may have difficulty in determining their structural details.
- (3) Colored film is frequently the most effective for identifying vegetation. The scale varies with the data needed, ranging from 1:5000 to 1:40,000. Vegetation can also be identified from differences in tone on black and white aerial photographs.
- (4) Stereopairs, vectographs, and anaglyphs are particularly useful in making terrain studies. A *stereopair* consists of two photographs of the same terrain taken from different positions. Usually they are taken from a position vertically above the area being photographed with about 60 percent of each photo (called the *overlap*) common to both photographs.

Examination with a stereoscope gives an exaggerated third-dimensional view of the terrain included in the overlap. A *vectograph* is a print or transparency in which the two photographs of the stereoscopic pair are rendered in terms of degree of polarization, presenting a stereoscopic image when viewed through Polaroid spectacles. An *anaglyph* is a picture combining two images of the same object, recorded from different points of view, as images of the right and left eye, one image in one color being superimposed upon the second image in a contrasting color. Viewed through a pair of light filters, the anaglyph produces a stereoscopic effect.

- (5) Controlled mosaics of an area provide an accurate map from which measurements of distances can be obtained. Their use in a terrain study should be confined to the analysis of major physiographic units, contrasting soil patterns, or differences in vegetation. The amount of detail provided for a thorough terrain analysis will depend upon the scale of the mosaic.
- (6) Information obtained from aerial and ground photographs should be correlated with other sources of information, such as published material, maps, personal reconnaissance, or reports from intelligence agencies.

20. Books, Periodicals, and Reports

a. General Sources. Valuable terrain information can be found in a wide variety of both technical and nontechnical books, periodicals, and reports published by governmental and private agencies. These include trade journals, economic atlases, tide tables, pilots' handbooks, tourist guides, and similar publications. Unpublished systematic records covering meteorological, hydrological, and similar scientific data prepared by government agencies, engineering firms, private societies, and individuals also contribute valuable terrain information. While utilized chiefly for terrain studies made by higher headquarters, material of this type, when locally available, can be of considerable value to lower echelons.

b. Intelligence Reports. Strategic intelligence studies prepared by Department of Defense agencies provide detailed terrain information concerning major geographical areas. Such studies include—

- (1) *National Intelligence Survey (NIS)*. This is a series of documents covering the countries of the world, presenting a concise digest of the basic intelligence required for strategic planning and for the operations of major units. Each survey describes in detail the pertinent terrain characteristics of a specific area, supported by descriptive material, maps,

charts, tables, and bibliographies, with reliability ratings assigned to all data.

- (2) *Engineer Intelligence Studies (EIS)*. These are a series of documents describing in detail those natural and man-made features of an area that affect the capabilities of military forces, particularly with reference to engineer operations. They are produced by the Office, Chief of Engineers.
- (3) *Engineer Reconnaissance Reports*. Reports summarizing data obtained by reconnaissance are a major source of terrain information at all levels. They are of particular value in providing current, detailed information about routes of communication and the availability of natural construction materials.

21. Captured Enemy Documents

Maps and other intelligence documents captured from the enemy often are of great value as sources of terrain information. Usually, enemy prepared military maps and terrain studies of enemy territory will be more up-to-date and detailed than our own. The processing of captured enemy documents is described in FM 30-15.

22. Interrogation

Interrogation personnel should be kept informed of the terrain information that is required by intelligence officers. Useful information about the area held by enemy forces frequently can be obtained from prisoners of war, deserters, liberated civilians, refugees, escapees, evadees, and cooperative enemy nationals.

23. Agencies

a. General.

- (1) Collection agencies include intelligence personnel, troop units, and special information services. FM 30-5 discusses the types and capabilities of these agencies.
- (2) All units within a command may be employed by the intelligence officer to secure terrain information. In addition, he may request higher headquarters to use their units and facilities to secure information he requires.

b. *Troops*. Reconnaissance missions to secure terrain information may be assigned to infantry, artillery, engineer, or armor units. Such missions may be accomplished by units specifically organized for reconnaissance or by other units assigned reconnaissance missions in addition to their normal activities.

c. *Aircraft*. Where ground reconnaissance of enemy-held territory is impractical, aircraft may be employed to secure information about the terrain. Air reconnaissance is the fastest means of gathering terrain information, although it may be limited by adverse weather or

enemy air-defense measures. Army aviation has a limited capability to maintain continuous surveillance over the battlefield.

d. Specialized Agencies.

- (1) An engineer terrain detachment usually is assigned to each field army. The detachment is composed of personnel in various fields of engineering and the natural earth sciences who prepare special terrain studies, and evaluate all types of terrain information, and serve as consultants to agencies faced with technical problems relating to the terrain.
- (2) Terrain information may be provided by personnel whose normal duties are not primarily concerned with terrain intelligence. These include military intelligence personnel of the MI Battalion, field army.

CHAPTER 4

TERRAIN STUDIES

Section I. GENERAL

24. Use of Terrain Study

a. A terrain study is an intelligence product which presents an analysis and interpretation of the natural and manmade characteristics of an area and their effects on military operations. It is prepared by the engineer at all echelons to provide the G2 with an analysis of the terrain for use in preparing the *analysis of area of operations* that forms part of his overall intelligence estimate for the echelon commander, and for use by other staff elements for planning and conduct of operations. The preparation of an analysis of area of operations is discussed in FM 30-5.

b. Above army level, terrain studies are prepared primarily for planning purposes principally to assist the commander and his staff. At lower levels, terrain studies are intended chiefly for use in tactical operations and include more detailed intelligence concerning the terrain and its effects.

c. Special studies devoted exclusively to certain terrain features or effects may be prepared to meet the requirements of a particular plan or operation. These are produced by technical personnel or teams, and include, but are not limited to, studies concerning—

- (1) Construction problems.
- (2) Movement.
- (3) State of ground.
- (4) Water resources.
- (5) Lines of communication.
- (6) Site selection.
- (7) Coast and landing beaches.
- (8) Inundation.
- (9) Urban areas.
- (10) Barriers.
- (11) Defenses.
- (12) Airborne landing areas.
- (13) Soils.
- (14) Rock types.
- (15) Drainage.
- (16) Climate.

- (17) Surface configuration.
- (18) Other military aspects.

25. Prerequisite Information

a. A terrain study is not the compilation of all the terrain intelligence available of some particular area, but only that information that has a direct bearing on some existing requirement. Accordingly the scope of a terrain study must be defined. Prior to initiating the study, the engineer must know the area to be covered, the mission and type operation, the specific information required by G2, and the time period to be considered.

b. Terrain intelligence is produced continuously at all echelons. The engineer maintains a file of intelligence data, drawing upon it for pertinent matter when he is directed to make a terrain study. Additional information is obtained from the sources and agencies discussed in chapter 3.

26. Format

a. Appendix II shows a checklist for terrain studies, and Appendix III presents an outline form for a terrain study. A specific terrain study will not cover every item on the form, but only those items applicable to the operation being planned. Used in this manner, the terrain study form insures uniformity of presentation yet permits the flexibility imposed by terrain analysis.

b. The primary requirements for a terrain study at army, corps, or division level is that it must present the intelligence in a form that can be easily utilized by field units. The study must be concise, presenting only pertinent information. Written description should be kept to a minimum. Intelligence should be presented graphically whenever possible.

27. Compilation

a. The format suggested for the compilation of the terrain study consists of three parts: the written text, a terrain study map, and a regional description section. A fourth major paragraph, *Analysis of Area of Operations*, is prepared by the intelligence officer. The scope of this paragraph is described in FM 30-5. The written text follows the sequence of the sample terrain study (app. IV). It presents the terrain intelligence called for in the applicable sections of the form. Tables and charts are used to simplify, amplify, and clarify the presentation. The written text should be as concise as possible.

b. Wherever possible, terrain intelligence should be presented on a terrain study map, based on a topographic map of appropriate scale. A map scale of 1:50,000 or 1:100,000 is usually utilized for battle groups and infantry divisions. Corps and Army Headquarters will

require a scale of 1:100,000 or 1:250,000. The terrain intelligence is overprinted on the topographic map (printed in gray monochrome) or is an overlay to the map. Appropriate symbols are used to present items of terrain intelligence. Movement conditions are portrayed by designated movement colors (app. IV).

c. Terrain features exist in certain patterns or combinations, and these combinations create distinctive terrain regions. Usually the area of study encompasses several terrain regions. The regional description section of the terrain study aids in providing the user with an understanding of the terrain by explaining the combined effect of the terrain features in the regions. This section consists of a sketch map delineating the terrain regions and of brief descriptions summarizing the terrain intelligence for each region. It may be printed on the back of the terrain study map. The data presented in the regional description section enables the user to evaluate the factors influencing movement and to interpret changes in movement which might be caused by changes in the weather.

28. Reproduction

This paragraph discusses the capabilities for the reproduction of terrain studies at army, corps, and division level.

a. The engineer topographic battalion assigned to army has extensive capabilities for map reproduction. The battalion can draft and reproduce in bulk the terrain study map described in paragraph 27. It can also perform the other printing and drafting necessary for the reproduction of terrain studies.

b. The engineer topographic company assigned to corps has basically the same capabilities as the topographic battalion in the type of work it can do, but is limited as to volume and equipment.

c. A division has no organic topographic units. Terrain studies are produced by means of duplicators which can produce a map-size overlay in several colors. The type and quality of terrain studies is limited only by the degree of skill and imagination on the part of the personnel who are responsible for this function.

29. Dissemination

a. The engineer intelligence officer disseminates the completed terrain study to the G2 and other interested staff elements. The G2 utilizes the terrain study according to the tactical situation and presents the resulting terrain estimate to the commander. If necessary, the terrain study is disseminated to subordinate and adjacent units.

b. The terrain study is also disseminated through engineer channels. Copies are sent to lower echelons to assist them in planning and preparing their own terrain studies. A copy is sent to higher

engineer headquarters, and another is sent through engineer channels to the zone of interior for use by the intelligence agencies of the Office of the Chief of Engineers.

Section II. BASIC COMPONENTS OF TERRAIN AND CLIMATE

30. General Considerations

a. The basic factors of terrain are discussed under item 2 of the terrain study form (app. IV). The factors discussed are climate, topography, and when applicable, coastal hydrography. Although climate and the oceanographic features of coastal hydrography are not elements of terrain, they have a direct influence on the terrain and are, in themselves, important considerations.

b. Appendix IV compiles the terrain intelligence on the area that is pertinent to the planned operation. The scope of the area will vary with the echelon performing the compilation. Terrain studies at higher echelons may present fairly extensive descriptions for planning purposes. Terrain studies at lower echelons, having a more definite direction and limit as to area, time, and purpose, restrict their descriptions to the intelligence applicable to the operation planned, for this more concise type of study.

c. Written and graphic descriptions can be used to describe the factors of the terrain. The application of these means is discussed in the following paragraphs.

31. Climate

a. Terrain features are affected by the climate, which includes such elements as visibility, temperature, precipitation, humidity, winds, clouds, and electrical disturbances. Not all of these factors are discussed in every terrain study, since the factors to be described and the manner of description depend on the area, time, and type of operation planned.

- (1) The area of operations influences the description of the climate. Terrain features also influence the climate of an area. A description of the climate of a large area can consider these terrain influences only generally, whereas a description of a small area, such as a single valley, can be quite specific. Further, the importance of certain elements of climate depends upon the area.
- (2) The time that a specific operation is due to commence determines the type of intelligence presented in the description. Climate data must be used if the starting data is more than a week or two in the future. (Weather predictions will be used by G2 in the terrain estimate for periods of 5 days or less.)

- (3) The type of operations planned determines the pertinent elements of climatic information to be furnished. Planning of airborne operations, amphibious operations, and other special operations requires knowledge of weather elements not usually required in normal ground operations. These considerations are discussed in greater detail in manuals pertaining to airborne and amphibious operations.

b. The means of describing various factors of climate are discussed below.

- (1) *Visibility.* The data necessary for describing visibility are discussed in chapter 5.
 - (a) Certain fixed data are best presented graphically. Times of sunrise, sunset, moonrise, moonset, BMNT, EENT, and phases of the moon are best presented on a chart to indicate periods of degree of visibility. Such a chart is included in the sample terrain study. Where pertinent, tide data can also be presented on this chart.
 - (b) Data on other deterring influences on visibility, such as clouds, fog, smoke, dust, or snowstorms, are discussed in the written text.
- (2) *Temperature.* This information is generally presented in tabular form in the written text. The presentation will vary depending upon the source of the data.
 - (a) Temperature predictions based solely on climatic studies cannot forecast the expected temperatures, but can describe the *range* of temperatures that can be expected in a particular location. These data can be presented in two ways. By the first method, the mean temperature, the mean maximum and mean minimum, and the absolute maximum and absolute minimum temperatures which can be expected for the period can be indicated. The mean temperature alone has little significance since it gives no indication of the range of the temperature variation. The second method is to tabulate the number of days of the period that the temperature can be expected to exceed or fall below stated temperatures.
 - (b) Temperature effects on other terrain features are described adequately when significant. The effect on soil trafficability and freezing or thawing of water bodies is particularly significant.
- (3) *Precipitation.* This information, based on climatic studies, can state the type and amount of precipitation encountered during a particular period; the number of days within that period on which certain amounts of precipitation can be expected; and the variability of precipitation from year to

year. A statement of the total amount of precipitation that can be expected over a period of time has little significance in itself, since a 3-inch rainfall means one thing when spread over 30 days and a totally different thing when concentrated in 1 day during the 30-day period. The effect of precipitation on other terrain features, particularly water bodies and the trafficability of soils, should be described in the written text.

- (4) *Winds.* Wind data based on climatic research present the direction, intensities, and duration that can be expected over a period of time. These data are best expressed graphically by means of a wind rose or may be referenced to the Weather Map Scale of Wind Velocity. Wind rose data may be secured from AWS when specifically required by a commander. The effect of wind on surface materials and on waves is described when pertinent (app. V).
- (5) *Humidity.* Exact descriptions of humidity are not usually necessary, but the effects of humidity on operations is described when significant. The description should consider fog conditions and the effect of humidity in reducing the efficiency of personnel or in creating problems of storage and maintenance of supplies and equipment.
- (6) *Clouds.* Data based on climatic records signify the approximate number of days during a specific period that a certain degree of cloud cover can be expected. Also, there is an indication as to what time of the day or night certain cloud coverage can be expected. Related conditions such as storms and fog are also described when applicable.
- (7) *Electrical disturbances.* This subject is discussed only when it has an important effect on proposed operations. The type of disturbance, its period of occurrence and duration, and its effect on planned operations are described in the written text when pertinent.

32. Natural and Manmade Features

a. Methods. Methods of indicating natural and manmade features in a terrain study are discussed in this paragraph.

b. Relief. Relief is described both symbolically and in the text to highlight significant relief features, but not to repeat the detail of a topographic map. Relief symbols are usually brown. The general picture of the relief of an area may be indicated by ridge and stream lining, which accentuates the major ridges and drainage patterns. This consists of emphasizing the streams by drawing over them with a heavy blue pencil and emphasizing ridges with a brown pencil. When emphasizing ridges, heavy lines are drawn along the topographic

crests. Ridge lining or stream lining can be used separately, if desired, but the combination of the two is more effective. Ridge and stream lining emphasises the compartmentation of an area, but does not show relative elevations or slope (fig. 4). Another method is to emphasize the principle contours of an area. This is done by tracing over certain critical contour lines with a heavy black pencil or by using different colored pencils to indicate different elevations. This method has the advantage of not obscuring details on the map (fig. 5). Sharp slopes, such as embankments, steep riverbanks, and cliffs are indicated by a red movement symbol when its traverse appears to be impracticable. In certain cases, an area may be cut by numerous draws and gullies which are significant but are not shown on topographic maps due to the fact that their depth is less than the contour interval. These draws and gullies are described in the text. The effect on movement is discussed under "movement" and illustrated graphically by movement symbols.

c. Draining and Hydrography. Since drainage features are subject to change at least seasonally, it is important to describe their current condition in the terrain study. The degree of detail employed in the description is usually determined by the echelon at which the study is prepared, and the primary purpose of the study itself. A higher echelon indicates only the major features on the terrain study map. A lower echelon study covering a smaller area can indicate the minor drainage features and give detailed descriptions of them.

d. Vegetation. Forests are indicated graphically. The type of trees (broadleaf and needleleaf), the density of the forest, and the range of trunk diameters are noted on the map. The text describes other significant vegetation in the area and the effect of weather on the vegetation. Vegetation may be discussed under concealment, fields of fire, obstacles, and any other pertinent aspects of the terrain.

e. Surface Materials. Higher echelon terrain studies usually include a soils map. At army and lower headquarters, this will not usually be feasible. A general description of the types of surface materials is included in the surface material paragraph of the study. The types of surface materials are discussed in greater detail in the descriptions of the separate terrain subareas. The effect of surface materials on movement is an important factor of the terrain study and is described graphically by movement symbols. Surface materials are also discussed in the sections on construction sites and construction materials.

f. Manmade Features. The terrain study describes those manmade terrain features which have particular significance or which require more detailed description to be of value. The more common man-made features are discussed below.

- (1) The road-bridge-bypass system is described because of its influence on vehicular movement. A higher echelon study may

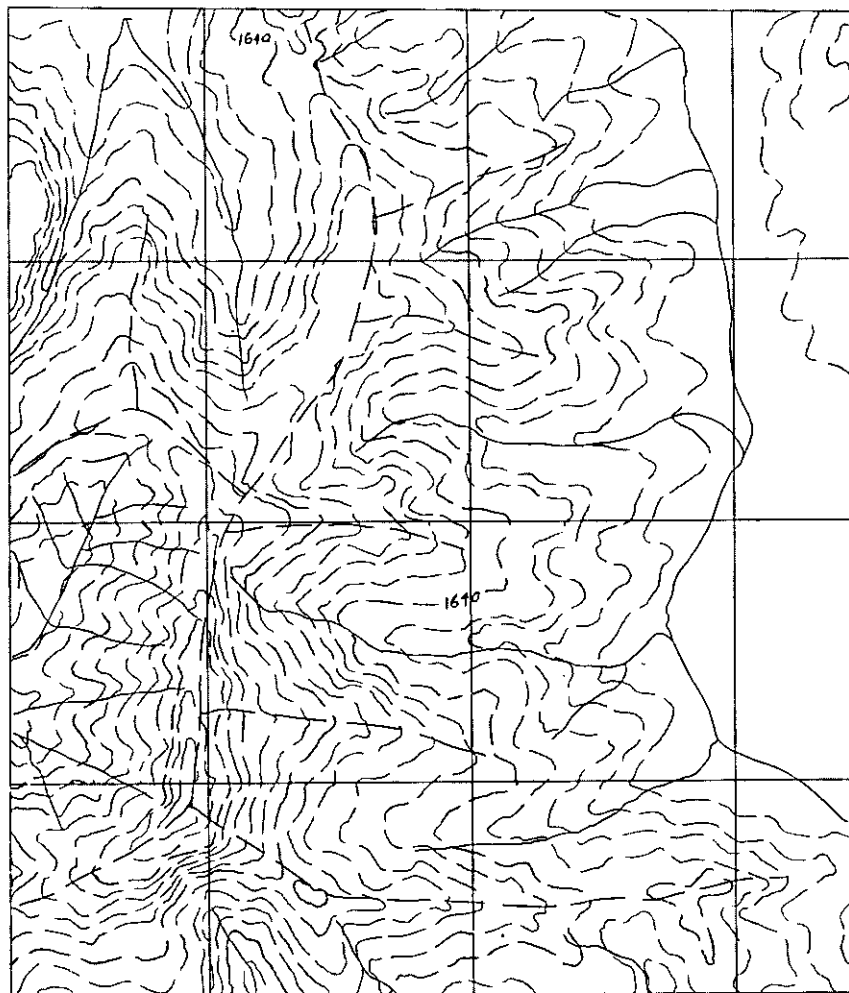


Figure 4. Ridge and stream lining.

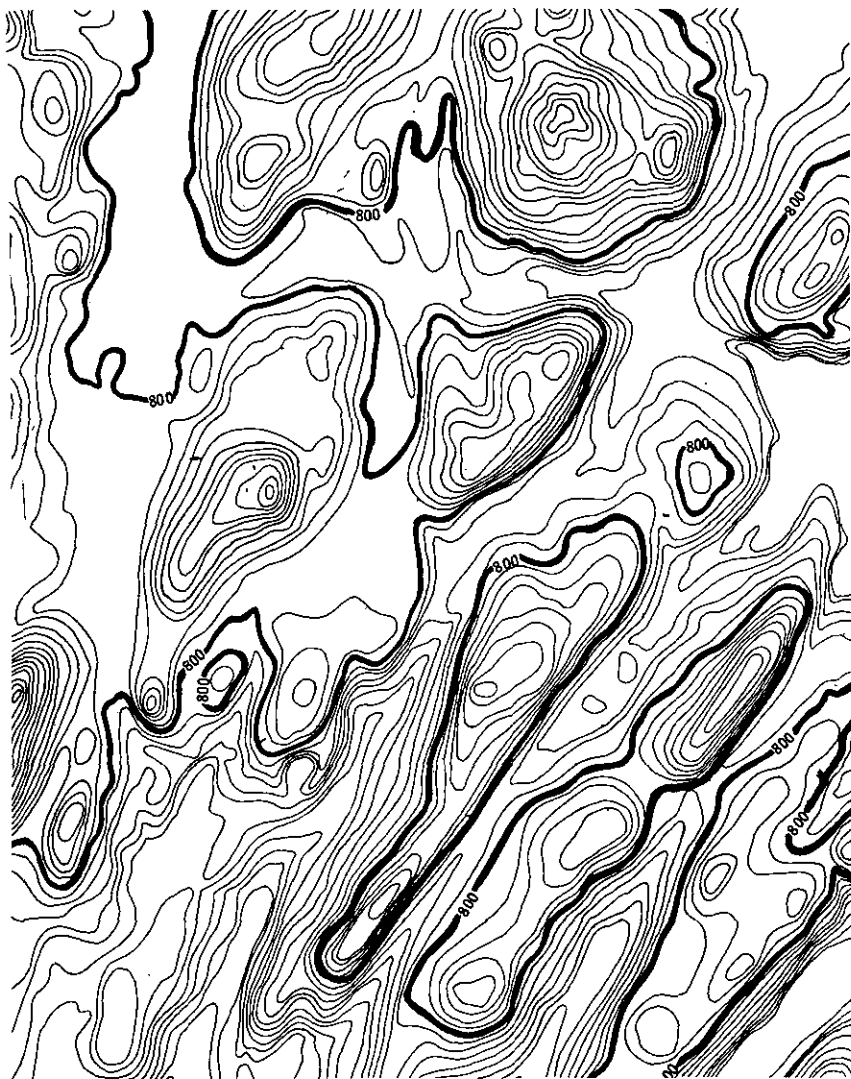


Figure 5. Contour emphasis.

describe graphically only the primary roads whereas a division study usually describes the secondary and tertiary systems as well. Important bridges and bypass sites are indicated. (See FM 5-36 for route classification symbols.)

- (2) Airfields of all types are described. Their locations are shown on the map by standard topographic symbols and an indication is given as to their size and condition. Further details are given in the text.
- (3) Principal cities and towns are indicated on the terrain study map. They are described further in the written text.

- (4) Railroads are shown on the terrain study. Detailed information is presented in the written text.
- (5) Hydrologic structures of all types are described. Detailed information is presented in the written text.

Section III. DESCRIBING MILITARY ASPECTS OF TERRAIN

33. General

a. Determining the military aspects of the terrain for a particular operation requires a knowledge of the terrain and of the operation planned. Not having complete knowledge of any specific military operation, the person preparing the terrain study should describe the military aspects in terms of generalized operations. G2 will interpret them in terms of the operation being planned. This is particularly true of key terrain features and avenues of approach.

b. Descriptions of the aspects of terrain vary with the echelon. At army level, descriptions are general; at division level they are more detailed and specific.

34. Observation

The description of observation includes an evaluation of the ground and air observation in the area, and a brief discussion of the terrain features in that area that affect observation. Periods of visibility are described by a visibility chart in the weather and climate section. The effect of the terrain on observation by special devices such as radar, infrared equipment, and sound-ranging devices is described when applicable. The description of observation is generally included in the text. A lower echelon study map may indicate the location of individual observation points.

35. Fields of Fire

The description of fields of fire in the terrain study is included in the text, and is primarily concerned with flat-trajectory weapons. The description includes a general evaluation and a discussion of the terrain features that affect fields of fire. Features which limit or restrict fields of fire are described in detail. Terrain features that create special problems in the use of high-trajectory weapons are described when they exist. (Areas of marsh or volcanic ash that smother explosive shells are examples of such features.) The possible effect of terrain on nuclear actions is described when pertinent.

36. Cover and Concealment

This includes a discussion of the problem of constructing installations to provide cover, such as foxholes, bunkers, and underground installations. The means available for providing cover from nuclear

action is discussed when applicable. Concealment is described in the text with reference to pertinent terrain features such as forests which are portrayed graphically. The amount of concealment and to what extent various type units can utilize it are discussed.

37. Obstacles

The description of obstacles includes a description of the general hindering characteristics of the terrain and a description of specific obstacles. The explanation of the general obstructive elements of the terrain is an overall description and includes terrain features which are unimportant singly, but which constitute obstacles cumulatively. Systems of irrigation or drainage ditches, terraces, and hedgerows are examples of such features. These are described in the text and indicated graphically by movement symbols. Specific obstacles such as rivers or escarpments, are described individually. Obstacles that are known to be impracticable for traverse of personnel or equipment are outlined by red hachuring. (This symbol must be used cautiously.)

38. Key Terrain Features

The determination of key terrain features requires a knowledge of the terrain, the objective, and plan of operations. As a rule the engineer officer or noncommissioned officer making this study does not have a complete knowledge of the plan of operations, and therefore he must determine those features that have a controlling effect on the surrounding terrain and list them as probable key terrain features for consideration by the G2. The description of these features includes a discussion of their significance.

39. Movement

The description of movement conditions is the most important and detailed of the descriptions of military aspects of the terrain. The description of movement in the text is devoted to a general evaluation of conditions for movement in the area and a discussion of the terrain features and weather conditions which affect movement. Movement is shown graphically in the terrain study map by color symbols which represent an evaluation of movement conditions. The effect of all terrain features is considered in the text on movement evaluation. The specific meaning of symbols as applied to the area of study are explained in the margin of appropriate classification symbols. A more complete discussion of areas of poor or doubtful movement than is possible on the terrain study map is contained in the regional description section to enable the commander to determine conditions under which movement is possible through the area.

40. Avenues of Approach

The determination of avenues of approach involves a summation of all other military aspects as they affect the mission of a particular force. Fixing the avenue of approach involves a tactical decision which is beyond the scope of the engineer intelligence officer. His role in the preparation of a terrain study is to present information on the available avenues of approach for consideration by the G2 and the commander. This information is included in the text. It includes a description of the avenues of approach and a brief discussion of their advantages and disadvantages.

41. Construction Materials

The description of construction materials presents information on the availability of construction materials in the area of operations. It includes data on the presence of developed and undeveloped sources of rock, sand, gravel, and aggregate, and of stocks of lumber, steel, and other construction materials. It is not a detailed report of the location of stocks or sources of materials, but presents general data on the availability of materials to indicate capabilities for construction in the area. Availability of building materials is discussed generally under military aspects of the terrain. The regional description section of the terrain study contains more detailed descriptions of the materials available in each region. Detailed reports on the sources of construction materials are prepared separately as required by engineer units.

42. Suitability for Construction

The description of construction sites includes a discussion of sites for roads, airfields, and other surface and underground installations. This description should be suited to the needs of the echelon for which the study is prepared. The description does not indicate specific sites, but describes the general suitability of the area for various types of construction. Building sites are discussed generally in the text. The regional description section contains a more detailed discussion of the suitability of each region for construction. Detailed reports on appropriate sites for specific construction projects are prepared separately as required by engineer units.

43. Water Supply

The description of water supply enumerates the sources of water available in the area and evaluates their suitability for use by the troops. It includes a discussion of natural water sources and water supply systems. When pertinent, the water requirements of the civilian population are discussed. Water supply is discussed in the text. The regional description section explains any peculiarities of water supply that may exist in any region.

Section IV. COASTAL HYDROGRAPHY

44. Describing Coastal Hydrography

a. Method of Presentation.

- (1) Descriptions of coastal hydrography are of interest primarily for amphibious operations. They differ from overland operations only in the method of transportation and type of routes by which they arrive at the area of operations.
- (2) The terrain study for an amphibious operation includes: written text, terrain study map, and regional description. These are the same elements which are in the land-operation study, but the terrain study for an amphibious operation must also include a means for presenting detailed intelligence about the landing area. This is done by extending the three elements of presentation mentioned above to include descriptions of the landing area, and by use of a fourth element, the landing area map. Application of this method of description to coastal hydrography is discussed below.

b. The written text is expanded to include a section on coastal hydrography. This section describes the features of coastal hydrography, such as sea approaches, beach area, sea and surf, and tides. The description is coordinated with the graphic presentation. The effect of other terrain features on coastal hydrographic conditions is also described. This includes the effect of inland surface materials on beach composition.

c. The terrain study map is extended to include the landing area. Since the terrain study map is of relatively too small a scale to be of value as a description of the landing area, it is generally used to depict the configuration of the coast line, location and length of the beaches, and location of exits from the beaches.

d. The regional description section is extended to include the landing area. The landing area may be described as a separate region or as part of other regions, whichever is appropriate to the situation.

e. The landing area map (fig. 6) may consist of a large-scale (1:4000 to 1:10,000) sketch map of the beach and nearshore area. The map is contoured to depict relief of the beach and nearshore, and a depth curve key is added. One or more profiles of the beach and nearshore are included in the map. A tide graph is included to indicate the height of water on the beach at any given time. A profile of the area to the rear of the beach, showing landmarks visible from the sea, is included if deemed necessary as a navigation aid for landing craft. Other data are included if pertinent to the operation.

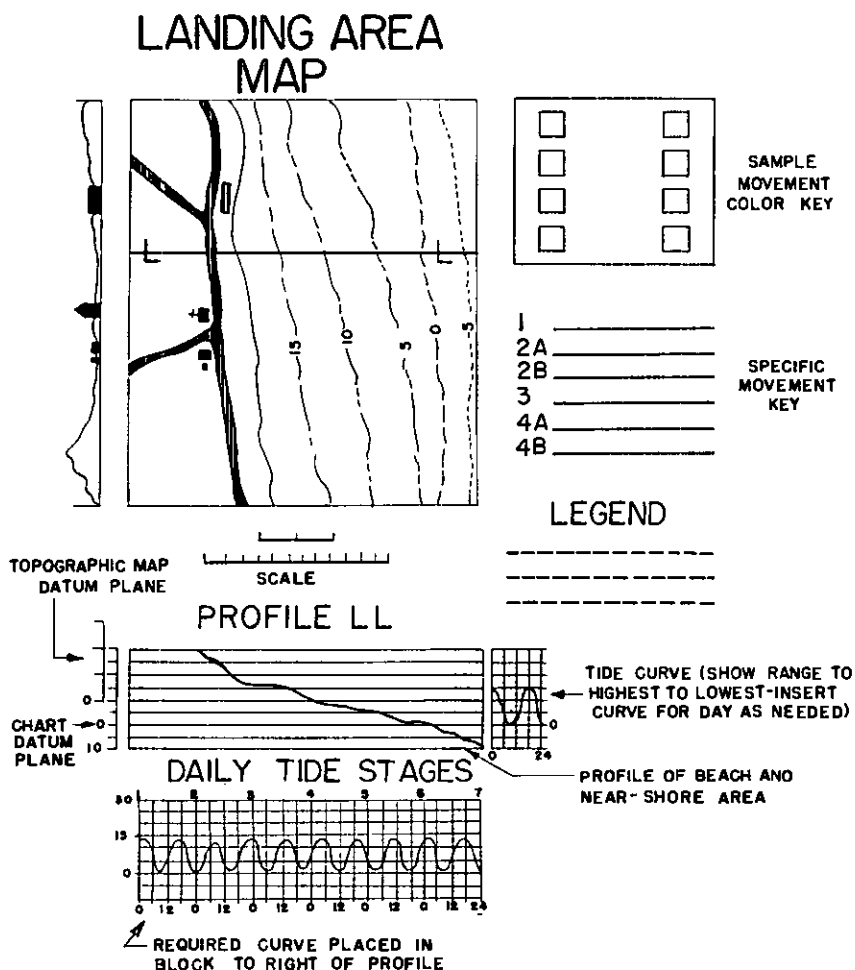


Figure 6. Landing area map.

45. Sea Approaches

a. Offshore Approaches. The offshore approaches are usually of interest only to naval forces and therefore are not described in the terrain study. When description is necessary, a hydrographic chart may be utilized.

b. Nearshore Approaches. The nearshore approaches are of primary interest to landing forces and, as such, require a detailed description.

- (1) The description in the text presents a general evaluation of the nearshore area, and describes bottom conditions and the effect of sea, surf, tides and currents. Also described are any special phenomena such as sea vegetation thick enough to

be classed as an obstacle, ice conditions, unusual or tricky currents, and biological currents, if any.

- (2) The landing area map presents a graphic description of the nearshore area. The general relief of the area is described by contours based on the hydrographic chart datum plane. Obstacles are located on the map and any special features are identified by special symbols. Representative profiles, as necessary, describe the gradient of the nearshore area. A tide curve, keyed to the profile, gives the height of water at any point, during the various stages of the tide.

c. Beaches and Beach Exits.

- (1) The text presents a general description of the beach area, covering such items as the capacity of the beach, its composition and trafficability, and the capacity of beach exits. Effects of sea and surf on the beach are also discussed.
- (2) The terrain study map describes the general configuration of the coast, the location and length of the beaches, and the beach exits.
- (3) The regional description deals with the beaches as part of topographic regions.
- (4) The landing-area map presents a detailed graphic description of the beaches. It portrays the dimensions of the beaches and the location of obstacle areas, and describes the beach exits. The colors used in the landing-area map conform to the color key used in all movement maps. The water tint usually extends to the high water shoreline, or at times to mean sea level, depending upon the mapping agency. One or more profiles are used to describe the beach gradient. If necessary, the area to the rear of the beach is included to indicate the position of landmarks as seen from seaward.

d. Sea and Surf. The sea and surf are described in the text. The description may discuss the sea and surf "climate" or predict sea and surf conditions, depending upon the available data. The factors described include the height of expected sea; the type, heights, and direction of resulting surf; the width of the surf zone; and the current caused by the sea and surf. When appropriate, areas of surf may be presented graphically on the landing-area map.

e. Tides. Tide data are presented graphically. Curves are used to portray times of occurrence of high and low tide, and can be incorporated in the visibility chart. A separate chart showing the range of tides during the period covered by the study is included in the margin of the landing-area map and is used in predicting the heights of water at any given time. Special tidal conditions and tidal currents are described in the text.

PART TWO
BASIC ELEMENTS OF TERRAIN INFORMATION
CHAPTER 5
WEATHER AND CLIMATE

Section I. WEATHER

46. Definition

Weather comprises the day-to-day changes in atmospheric conditions. The physical properties and conditions of the atmosphere that must be measured or observed to describe the state of the weather are termed the *weather elements*.

47. Air Temperature

a. Definition. Air temperature is the degree of hotness of freely circulating air as measured by a thermometer that is shielded from the sun. The thermometer is calibrated by using the melting point of ice and the boiling point of water at sea level as standard references. In most English-speaking countries, the Fahrenheit scale is used, with the melting point of ice designated as 32° F. above zero and the boiling point of water as 212° F. above zero. Countries using the metric system employ the centigrade (Celsius) scale, with the freezing point of water designated as 0° C. and the boiling point, 100° C. In the United States, surface air temperatures are indicated in degrees Fahrenheit and upper air temperatures in degrees Centigrade. Temperatures may be converted from one of these scales to the other by use of the following formulas:

$$C = \frac{5}{9} (F - 32^{\circ})$$

$$F = \frac{5}{9} C + 32^{\circ}$$

b. Recording. Temperature data may be recorded in the following forms:

- (1) *Mean daily temperature.* Average of daily maximum and minimum temperatures for any specific day.
- (2) *Mean monthly temperature.* Average of daily mean temperatures for any specific month.
- (3) *Mean annual temperature.* Average of daily mean temperatures for any specific year.

- (4) *Mean annual range.* Difference between the mean monthly temperatures of the warmest and coldest months.
- (5) *Diurnal variation.* Temperature variations during the day.
- (6) *Normal values, or long-term mean.* The average of temperature values for the entire period of record, generally the past 30 years. These values usually are used to evaluate the climate.
- (7) *Extreme values.* The highest and lowest temperatures of record for any specified day, month, or year.
- (8) *Length of freezing period.* Number of days with minimum temperature below freezing.

c. Use of Data. Mean annual temperatures usually are employed to provide a general definition of the type of climate, and the mean annual range to indicate its variability. Extreme values shows the limits which must be anticipated in the climate being considered. Temperatures also are recorded at various altitudes above the ground level in order to provide data for estimating certain types of nuclear-weapon effects.

48. Atmospheric Pressure

a. Atmospheric pressure is the force exerted on a unit of area by the weight of the atmosphere from the level of measurement to the top of the atmosphere. At sea level this pressure is approximately 14.7 pounds per square inch. Mean sea level is used as a reference for surface weather observations, and pressure measurements are shown on weather maps and climatic charts as if the entire surface of the earth were at sea level. Atmospheric pressures are recorded at various altitudes to provide data for estimating nuclear-weapon effects.

b. The standard device for measuring atmospheric pressure is a mercurial barometer which balances the weight of the atmosphere with a column of mercury. At sea level the pressure exerted by dry air at 32° Fahrenheit is approximately 29.92 inches. For some scientific purposes, it is desirable to indicate atmospheric pressure in units of pressure (weight per unit of area) rather than in units of length (inches). In the metric systems, a *bar* is the unit of measure. The *millibar* (1/1000 of a bar) is used in meteorology to designate the value of atmospheric pressure. The standard sea level pressure is 1013.2 millibars. One millibar equals 0.03 inches of mercury.

c. Barometer readings of about 29.92 inches generally indicate low-pressure areas and those with higher readings usually indicate high-pressure areas. In general, cold air, being heavy and dense, causes high barometric pressures, while hot air, which is light and thin, causes low pressures. High-pressure systems usually are associated

with fair, dry weather; low-pressure systems, with unsettled, cloudy conditions.

49. Winds

a. *Wind* is air in motion and results from differences in atmospheric pressure. A wind is described by its direction and speed.

b. The direction of a wind is the direction from which it is blowing. A wind coming from the north, for example, is termed a north wind. Wind direction is reported in air weather observations to the nearest 16 points of the compass.


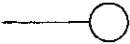
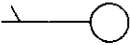
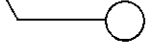
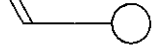
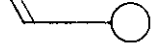
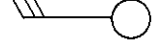
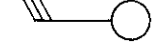
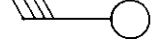
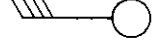
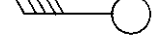
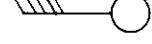
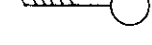
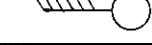
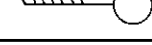
c. Wind velocities are reported by the air weather service in knots. A weather map scale of wind velocity (fig. 7) is used as an aid in estimating wind speed.

d. Over irregular terrain, a wind does not move with a steady force or direction, but as a succession of gusts and lulls of variable speed and direction. These *eddy currents*, caused by friction between air and terrain, are called *gusts* or *turbulence*. Turbulence also results from unequal heating of the earth's surface, the cooler air of adjacent areas rushing in to replace the rising warm air from heated areas. Usually the turbulence produced by surface friction is intensified on a sunny afternoon.

e. Local pressure and wind systems are created by valleys, mountains, and land masses that change the weather characteristics of areas. Since land masses absorb and radiate heat more rapidly than water masses, the land is heated more than the sea during the day and cools more at night. In coastal areas, warm air over the land rises to a higher altitude and then moves horizontally out to sea. To replace this warm air, the colder air over the water moves on to the land, creating the so-called *sea breeze*. The circulation is reversed at night, so that the surface air moves from the land to the sea, resulting in a *land breeze*.

f. Heated by the daytime sun, the air in contact with a mountain slope becomes lighter than the surrounding air and rises up the slope, being replaced by denser, colder air. This air movement is called a *valley wind* because it appears to be flowing up from the valley. At night the air in contact with the slope becomes colder and more dense, sinking down along the slope to create a mountain breeze that seems to flow out of the mountain. Mountain breezes generally are stronger than valley winds, especially in the winter.

g. A *chinook* (North America) or *foehn* (Europe) (fig. 8) is a phenomenon that occurs in winter and spring on the lee or downwind side of mountain ranges over which there flows a steady crosswind of moisture-laden air. As this air rises over the windward side of the mountains it expands and cools rapidly, producing clouds and precipitation. As the air moves down the lee side of the mountain range

WEATHER MAP INDICATION	VELOCITY KNOTS *	GENERAL DESCRIPTION	SPECIFICATIONS
	Less than 1	Calm	Calm; smoke rises vertically
	1 to 2	Breeze	Direction of wind shown by smoke drift; but not by wind vanes
	3 to 7	Breeze	Wind felt on face; leaves rustle; ordinary vane moved by wind
	8 to 12	Breeze	Leaves and small twigs in constant motion; wind extends light flag
	15	Breeze	Raises dust, loose paper; small branches are moved
	20	Breeze	Small trees in leaf begin to swing; crested wavelets form on inland waters
	25	Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty
	30	Breeze	Whole trees in motion, inconvenience felt walking against wind
	35	Gale	Breaks twigs off trees; inconvenience felt walking
	40	Gale	Same as above
	45	Gale	Slight structural damage occurs; (chimney pots; slate, shingles removed)
	50	Storm	Seldom experienced inland; trees uprooted; considerable structural damage occurs
	55	Storm	Very rarely experienced accompanied by widespread damage
	60	Storm	Same as above
	65	Hurricane	

* 1 Knot = 1.15 mph

Figure 7. Weather map scale of wind velocity.

it compresses and warms. As a result, there are warm, dry winds on the lee side of the mountains.

h. Katabatic winds are caused by the descent of downslope air through the action of gravity. They are typical of the Greenland coast, which is essentially a high plateau sloping abruptly to the sea



Figure 8. Chinook or foehn effect.

along an irregular coastline cut by many fiords. The central plateau area remains ice-covered throughout the year, developing extremely cold air masses which frequently drain off through the fiords to the sea and attain a near-hurricane speed. At sea level the winds remain relatively cold and very dry. Similar winds are the *bora*, which drain off the southern Alps and the Balkan Plateau into the Adriatic Sea, and the *mistral* of the Rhone Valley in France.

i. A *monsoon wind* is a wind of changing direction common to subtropical areas. It blows from the land to the sea in winter and in the reverse direction in summer. The summer monsoon season is characterized by extensive cloudiness, widespread rain, fog, and in some areas by intense thunderstorms. The winter monsoon season is characterized by dry air and relatively cloudless skies.

50. Humidity

a. Water vapor is the most important constituent of the atmosphere that determines weather phenomena. While the oceans are the primary source, a limited amount of water vapor also is furnished to the atmosphere from lakes and rivers, snow, ice fields, and vegetation. The percentage of water vapor by volume in the air may vary from practically zero in deserts to 4 or 5 percent in humid tropical areas.

b. *Humidity* is the term used to describe the amount of water vapor in the air. The amount that the air actually contains compared with what it could hold at a given temperature is termed the *relative humidity*. When a specific air mass holds all the moisture that it can at a given temperature, it is described as being *saturated*, and if it holds less than its possible maximum, as *unsaturated*.

c. The *dew point* is that temperature at which the air becomes saturated. The higher the dew point, the greater amount of water vapor there is in the air. The closer the dew point temperature is to the actual temperature, the greater the likelihood of condensation. Condensation results when the capacity of the atmosphere to hold water is reduced by cooling, so that the water vapor in the air is changed to visible moisture such as fog or clouds.

51. Clouds

a. Clouds are masses of condensed moisture suspended in air in the form of minute water droplets. They are classified according to their form or appearance and by the physical processes producing them. The air weather service reports the type of clouds present, the heights of the cloud bases, the amount of cloudiness, and the direction in which the clouds are moving.

b. Cloud amounts are reported in terms of the fraction of the sky that is covered by clouds (fig. 9). The following terms are used:

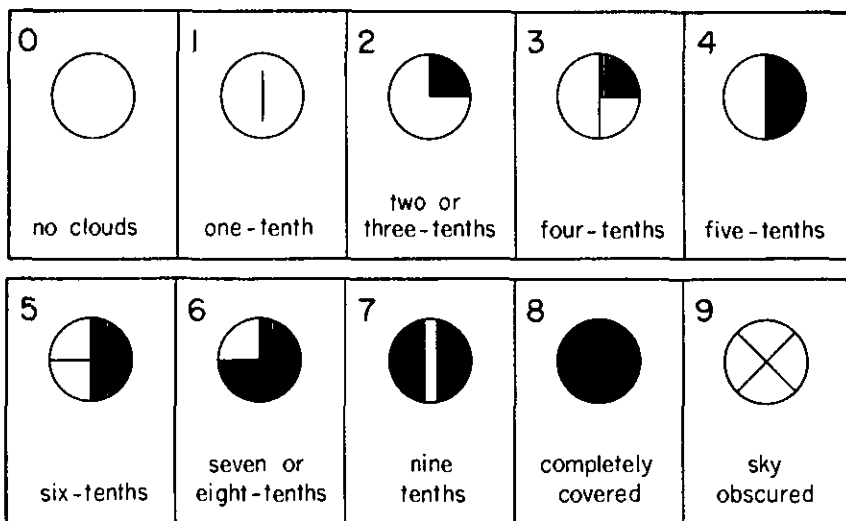


Figure 9. Cloud coverage symbols.

(1) *Clear*. No clouds, or less than 0.1 of the sky covered.

(2) *Scattered*. 0.1 to 0.5 of the sky covered.

(3) *Broken*. 0.6 to 0.9 of the sky covered.

(4) *Overcast*. More than 0.9 of the sky covered.

c. Cloud heights are reported in hundreds of feet above the ground. The heights of clouds below 5,000 feet are reported to the nearest 100 feet; clouds from 5,000 to 10,000 feet, to the nearest 500 feet, and clouds above 10,000 feet to the nearest 1,000 feet. The term *ceiling* is used by forecasters to give an indication of the amount and height of the bases of the clouds. It is defined as the lowest height (altitude) at which all clouds at or above that altitude cover more than one half of the sky. Heights are generally considered in relation to the main level of the terrain in the vicinity.

d. Cloud direction is the direction from which the clouds are moving. It is reported according to the eight points of the compass.

e. According to their appearance, clouds are either *cumiliform* or *stratiform*. Cumiliform clouds are formed by rising currents in unstable air. Stratiform clouds result from the cooling of air in stable layers.

(1) Cumiliform clouds are dense with vertical development. The upper surface of a cumiliform cloud is dome-shaped, while the base is nearly horizontal. Usually clouds of this type are separate from each other and rarely cover the entire sky. The precipitation from cumiliform clouds generally is showery in nature.

(2) Stratiform clouds usually occur in layers that may extend from horizon to horizon, without the vertical development of

cumiliform clouds. Precipitation from this type of cloud usually is in the form of light continuous rain, drizzle, or snow.

f. Clouds may be grouped into four families (fig. 10)—

- (1) *High.* Cirrus, cirrostratus, cirrocumulus.
- (2) *Middle.* Altostratus, altocumulus.
- (3) *Low.* Stratus, nimbostratus, stratocumulus.
- (4) *Vertical development.* Cumulonimbus for an example.

g. High clouds usually occur at heights of from 20,000 to 40,000 feet, although they may be found at much lower altitudes in polar regions. They are composed of ice crystals. The characteristics of the major cloud types in this group are as follows:

- (1) *Cirrus.* This is a delicate white fibrous cloud that often appears bright yellow or red from the reflection of light from a

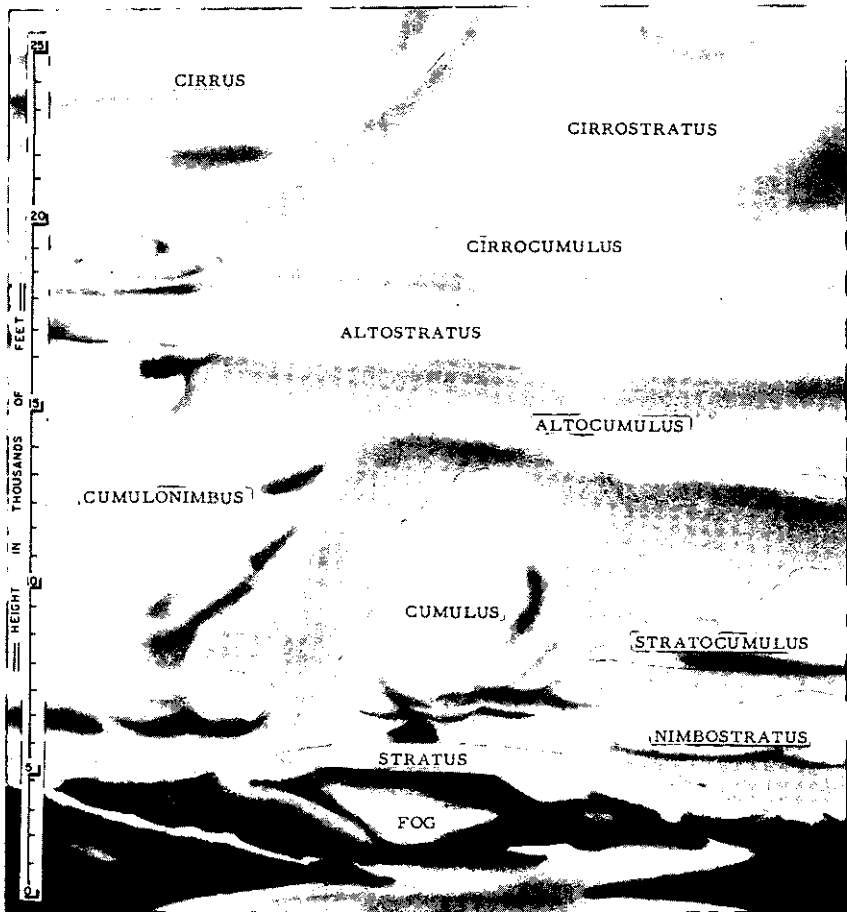


Figure 10. Major cloud types.

rising or setting sun. Cirrus clouds may appear as isolated tufts, featherlike plumes, or streaks with upturned ends often referred to as *mare's tails*. Because of their thinness, cirrus clouds do not blur the outlines of the sun or moon, and usually do not make an appreciable change in the appearance of the sky.

- (2) *Cirrostratus*. These are thin, whitish veils of clouds that give the sky a milky look. Usually they can be distinguished from cirrus clouds by the halo which light from the sun or moon produces in them.
- (3) *Cirrocumulus*. Clouds of this type consist of patches of small, rounded masses or white flakes arranged in groups or lines.

h. Middle clouds usually occur at altitudes of 6,000 to 20,000 feet in the middle latitudes (30° to 60°). They are found at altitudes near the lower limit of this range in the colder seasons, and at altitudes near the upper limit in the warmer seasons. The major types are—

- (1) *Altostratus*. Clouds of this type appear as a veil of gray or bluish fibrous clouds, the thinner forms resembling the thicker forms of cirrostratus. Altostratus clouds are associated with smooth or stable air layers, and occasionally they produce light rain or snow.
- (2) *Alto cumulus*. These occur in a layer or as a series of flattened, rounded air masses. They occur in a variety of forms, and may exist at several levels at the same time.

i. Low clouds usually have bases below 6,000 feet and include the following types:

- (1) *Stratus*. These form a low layer resembling fog, although they do not rest upon the surface. They give the sky a hazy appearance. Normally the base of stratus clouds appears ragged, so that it is difficult to estimate their height. Layers of stratus clouds may cover hundreds of thousands of square miles. Usually they are thin, and range in thickness from a few hundred feet to several thousand feet. Frequently, stratus clouds are accompanied by layers of fog, haze, or smoke between their bases and the ground. Visibility is very poor under stratus clouds, and precipitation from them usually is in the form of light snow or drizzle.
- (2) *Nimbostratus*. Clouds of this type form a low, dark gray layer. Precipitation usually is in the form of continuous rain or snow of variable intensity. Because of its thickness, sometimes more than 15,000 feet, the nimbostratus is frequently classified as a cloud of vertical development.
- (3) *Stratocumulus*. This type of cloud forms a lower layer of patches of rounded masses or rolls. The base of the strato-

cumulus usually is higher and rougher than the stratus clouds. Frequently these clouds change into the stratus type.

j. Vertical development clouds cannot be classified according to height, since they extend through all the levels assigned to other cloud groups. The bases vary from 500 feet to 10,000 feet or higher, while the tops may vary from 1,500 feet to more than 40,000 feet. They all occur in relatively unstable air and frequently are associated with strong vertical currents and intense turbulence. In this category are the following:

- (1) *Cumulus*. Clouds of the cumulus type are dense, with vertical development. The base is horizontal and uniform in height above the earth, with a top that is domed or cauliflower-like in shape. Cumulus clouds appear white when they reflect sunlight toward the observer, but when viewed from directly underneath or when they are between the observer and the sun, they may appear dark with bright edges. Over land, cumulus clouds tend to develop during the warming of the day, dissipating at night when the earth's surface cools. Over water, cumulus clouds tend to develop at night as the water surface remains warm while the air mass cools slightly.
- (2) *Cumulonimbus*. Clouds of this type are heavy masses which extend to great heights. Their upper portions resemble mountains or towers capped with a fibrous texture. They develop only in unstable air. Cumulonimbus clouds are distinguished from cumulus clouds chiefly by the veil of ice crystal clouds which surrounds their upper portions. Thunderstorms, squalls, turbulence, and hail are characteristic of cumulonimbus clouds.

52. Precipitation

a. Precipitation (fig. 11) is visible moisture that falls from the atmosphere, such as rain, sleet, snow, hail, drizzle, or combinations of these. As an air mass rises, its ability to hold moisture decreases and clouds form. When the cloud droplets become too large to remain in suspension, rain occurs or if the air temperature is below freezing, snow is formed. *Sleet* is frozen rain formed by droplets passing through a layer of below-freezing air. *Hail* consists of rounded particles composed of layers of ice falling from cumulonimbus clouds with strong updrafts. Raindrops are carried to high altitudes and frozen into ice pellets. They then fall and are carried up again by the updraft until the weight of the pellet is greater than the force of the updraft, whereupon it falls to earth. *Freezing rain* falls from the air in liquid form but freezes upon contact with objects on

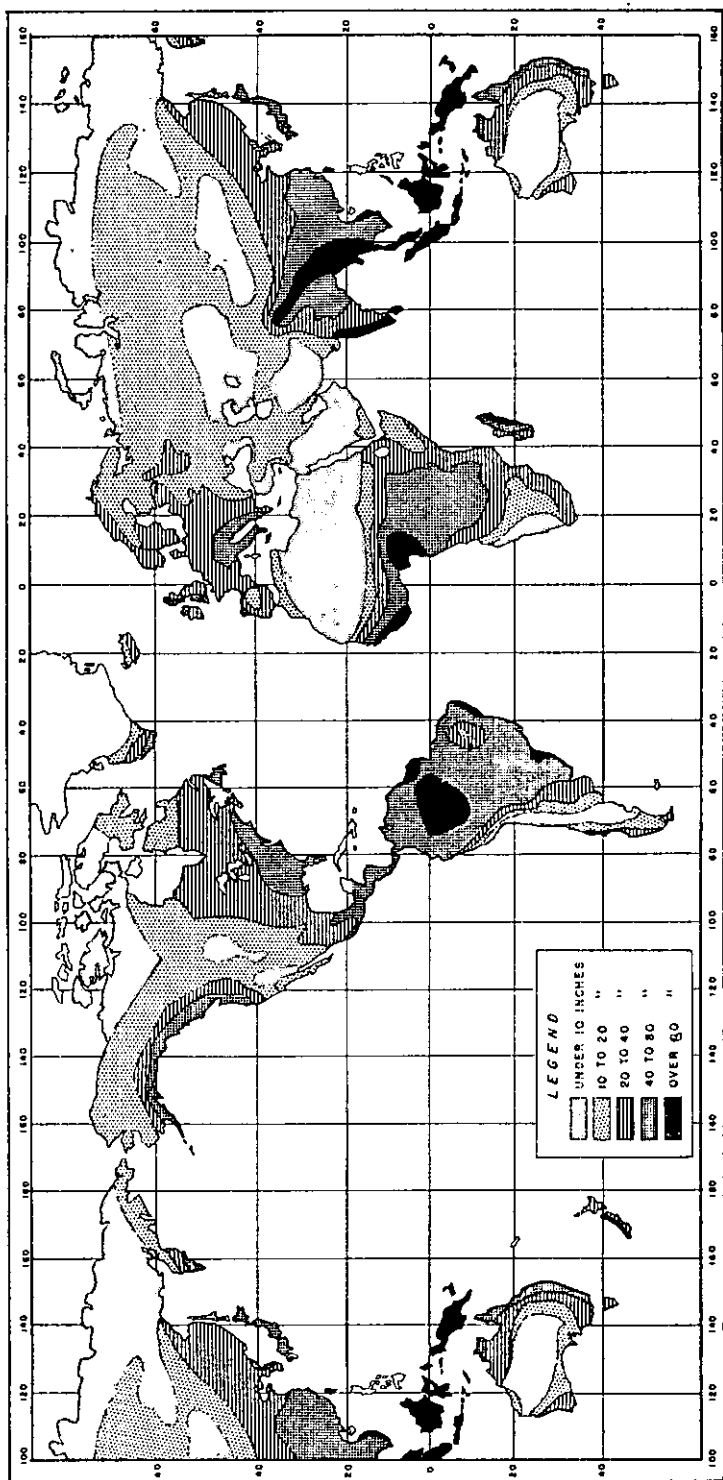


Figure 11. World rainfall.

the surface that are at a temperature below the freezing point. The ice formed on these surfaces is called *sheet ice*.

b. Air weather service observations include information on the form of precipitation and its character, intensity, and amount.

c. The character of precipitation refers to its duration and to changes in its intensity. It is reported as *continuous*, *intermittent*, or *showery*. Continuous precipitation is that in which the intensity increases or decreases gradually. Intermittent precipitation is characterized by a gradual change in intensity, but ceases and recommences at least once an hour. Showery precipitation is marked by rapid changes in intensity and by starting and stopping abruptly.

d. The intensity of precipitation is determined on the basis of its rate of fall. It is described as follows:

- (1) *Very light*. Scattered drops or flakes which do not completely wet an exposed surface, regardless of duration.
- (2) *Light*. 0.01 inch in 6 minutes.
- (3) *Moderate*. More than 0.01 to 0.03 inch in 6 minutes.
- (4) *Heavy*. More than 0.03 inch in 6 minutes.

e. The intensity of snow and drizzle is determined on the basis of the reductions in visibility which result, as follows:

- (1) *Very light*. Scattered drops or flakes which do not completely wet an exposed surface, regardless of duration.
- (2) *Light*. Visibility $\frac{5}{8}$ statute mile or more.
- (3) *Moderate*. Visibility less than $\frac{5}{8}$ statute mile, but not less than $\frac{5}{16}$ statute mile.
- (4) *Heavy*. Visibility less than $\frac{5}{16}$ statute mile.

f. The amount of precipitation is expressed in terms of the vertical depth of water (or melted equivalent in the case of snow or other solid forms) accumulated within a specified time on a horizontal surface. This is expressed to the nearest 0.01 inch. A depth of less than 0.005 inch is called a *trace*. In the case of snow, both the actual depth and the equivalent in water are required. Snow depth is measured to the nearest whole inch, and less than 0.5 inch is termed a trace. The water equivalent of snow is determined by melting a representative sample and measuring the resulting depth of water. As an average figure, 10 inches of snow are considered to be equivalent to 1 inch of water, although this is subject to wide variation. The depth of snow is of concern in estimating the trafficability of a snow-covered area, while the water equivalent is significant for problems involving water supply, flood prediction stream flow, and drainage.

53. Fog

a. *Fog* is defined as a mass of minute water droplets suspended in the atmosphere at the surface of the earth. It is formed by the condensation of water vapor in the air.

b. The most favorable conditions for the formation of fog are an abundance of water vapor, high relative humidity, and a light surface wind. A light wind tends to thicken fog. Increasing wind speeds will cause fog to lift or to dissipate.

c. Fog usually is more prevalent in coastal areas than inland because there is more water vapor in the atmosphere. Inland fogs may be very persistent in industrial regions. In most areas of the world, fog occurs more frequently during the colder seasons of the year than it does in the warmer seasons.

54. Storms

a. *Thunderstorms.*

- (1) A thunderstorm is a local storm accompanied by lightning, thunder, strong gusts of wind, heavy rain, and sometimes hail, usually lasting for no more than an hour or two. In most cases, a thunderstorm is characterized by turbulence, sustained updrafts and downdrafts, precipitation, and lightning.
- (2) When a thunderstorm reaches its mature stage and the rain begins, a downdraft starts in the lower and middle levels of the storm. This large body of descending air causes strong, gusty surface winds that move out ahead of the main storm area, often resulting in a radical, abrupt change in wind speed and direction termed the *first gust*. In general, the strongest thunderstorm winds occur on the forward side of the storm where the downdraft first reaches the surface. The speed of a thunderstorm wind may reach 50 to 75 miles per hour for a short time.

b. *Tornadoes.* Tornadoes are circular whirlpools of air which range in size from about 100 feet to one-half mile in diameter. A tornado appears as a rotating funnel-shaped cloud extending toward the ground from the base of a thundercloud. The low pressure and the high wind speeds encountered in the center of the tornado are very destructive. The paths of tornadoes over the ground usually are only a few miles long and the tornadoes move at speeds of 25 to 55 miles per hour. Although the maximum wind speeds associated with tornadoes never have been measured directly, property damage and other effects indicate that they may exceed 500 miles per hour. When they occur over water, tornadoes are termed *waterspouts*.

c. Tropical Cyclones.

- (1) A tropical cyclone is a low-pressure system of cyclonic winds that forms over tropical water areas (fig. 12). These storms are known by various regional names. Those of great intensity are called *hurricanes* in the Atlantic and Eastern Pacific Oceans, *typhoons* in the Western Pacific Ocean, *cyclones* in the Indian Ocean, and *willi willi* in Australia. The average life span of a tropical cyclone is 6 days, although some last only a few hours and others as long as 2 weeks.
- (2) Tropical cyclones of hurricane intensity are characterized by extremely strong and gusty surface winds, with speeds of 75 to more than 150 miles per hour; continuous intense rain in the central area, and a relatively calm area near the center known as the *eye*. These storms vary in size from 50 to 500 miles in diameter.
- (3) The precipitation associated with tropical cyclones is extremely heavy. They are frequently accompanied by violent thunderstorms, with the heaviest rainfall usually occurring some distance ahead of the eye of the moving cyclone. Abnormally high tides are a common companion of hurricanes and are responsible for a great amount of damage.

55. Weather Forecasts

a. *General.* A weather forecast is a prediction of the weather conditions expected to occur at a place, within an area, or along a route at a specified future time. The accuracy and reliability of weather forecasts depend upon a number of factors, including the climatic characteristics of the forecast area, the amount of weather data available, the reliability of weather communications facilities, the length of the forecast period, and the experience of the forecaster. Other factors being equal, the reliability of forecasts generally decreases as the length of the forecast period increases.

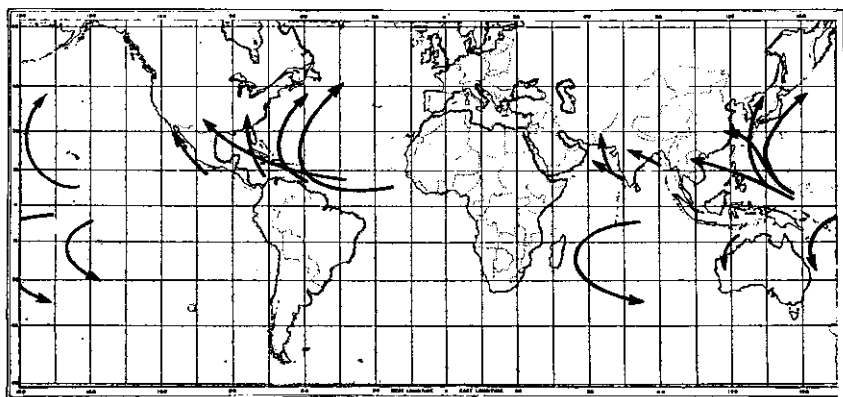


Figure 12. Tropical cyclones.

b. Format. Weather forecasts may be presented in coded (numerical), graphical (pictorial), or written (plain language) format. Normally, weather forecasts for use by Army units will be issued in plain language form. Because forecasts are subject to sudden change, they are usually transmitted by electrical means. Abbreviations are used extensively. The abbreviations used in weather messages are contained in JANAP 169 and in the Civil Aeronautics Administration publication, *Contractions*.

c. Sources. Weather forecasts and special studies are provided by agencies of the Air Weather Service under the direction of the theater Air Force commander. Usually a *weather central* is established at theater headquarters, a *weather center* at field army or army group headquarters, and a *tactical weather station* at corps headquarters. Division and lower units receive weather forecasts through intelligence channels (app. V).

d. Types of Forecasts.

- (1) *Short-period forecasts* cover a period up to 48 hours in advance of issue, giving detailed values of the weather elements expected to occur during the period and the time of anticipated weather changes. They are sufficiently reliable for use in detailed short-range planning.
- (2) *Medium-period forecasts* cover a period of 3 to 5 days, and *extended-period forecasts* cover periods in excess of 5 days. They are less detailed and specific than short-period forecasts. Usually the weather information is expressed in terms of departure from normal conditions and is suitable only for preliminary planning purposes.
- (3) *Severe weather forecasts* provide warnings of weather conditions that will create unusual difficulties. Examples of severe weather include tropical cyclones, thunderstorms, strong and gusty surface winds, heavy precipitation, and extremes of temperature. The Air Weather Service furnishes such warnings when requested by commanders, based upon the needs of their particular unit or installation. The weather conditions that will be critical vary with the type of unit or installation. For example, one unit may require warnings of winds in excess of 15 to 20 knots, while another may not be adversely affected by wind until the speed reaches 35 to 40 knots or more.
- (4) *Radiological defense forecasts* are special forecasts of winds and temperatures aloft used to determine the area that would be covered by a nuclear fallout. The information is presented in a numerical code form.

56. Weather Intelligence

a. General. *Weather information* is information concerning the condition and behavior of the atmosphere at a given place at a given time.

b. Dissemination. Timeliness is the critical factor in disseminating weather reports and forecasts. Normally they are transmitted by radio or teletype. Weather information is incorporated in such documents as the intelligence estimate, periodic intelligence report, or analysis of area of operations.

c. Responsibility of Intelligence Officer. The intelligence officer at corps and lower levels is responsible for—

- (1) Determining the weather information requirements and submitting them through channels to the Air Weather Service.
- (2) Informing subordinate units of the weather data required by the Air Weather Service and instructing them in the procedure for collecting and forwarding the data.
- (3) Disseminating weather information.
- (4) Coordinating with G3/S3 in the weather training of subordinate units.

d. Weather Requirements.

- (1) Weather requirements are of two types—those established by the Army and passed to the Air Weather Service for action, and those established by the Air Weather Service and passed to the Army for action. The intelligence officer coordinates all activities directed toward satisfying these requirements. At division and higher levels this coordination is effected through the Air Force Staff Weather Officer, a special staff officer at those echelons. Below division, the intelligence officer requests Air Weather Service support through intelligence channels.
- (2) Army weather requirements may include climatic information to be used in the planning phase of an entire campaign or operation, weather forecasts, reports of current weather, and weather summaries. Under conditions of nuclear warfare, timely and accurate weather data, particularly that concerning upper air wind speeds and direction, is essential in fallout predictions. Fallout predictions are required both for friendly and enemy employment of nuclear weapons.
- (3) Requests for specific weather information received by the intelligence officer are evaluated to determine whether or not the information can be secured by organic agencies before they are forwarded to the Air Weather Service. In all cases, before forwarding the request the intelligence officer insures that requests from various units do not overlap and that they cannot be fulfilled from information already available.

e. Army Information Sources. Weather data required by the Air Weather Service from Army units may be secured by artillery meteorological sections, Chemical Corps units, Army aviation, and forward combat troops. Artillery meteorological sections are capable of making winds-aloft observations and of determining upper air pressure, temperature, and humidity. Chemical Corps smoke battalions can furnish information concerning surface winds and temperature. The pilots of Army aircraft are capable of reporting weather conditions within their area of flight operations. Forward combat units can provide weather data obtained by visual observation, and if required, they may be equipped with instruments for obtaining additional weather data.

f. Interpretation. An intelligence officer does not discharge his weather responsibilities merely by disseminating verbatim the weather forecast that he receives from higher headquarters. He must interpret it in relation to the weather requirements of particular operations. He also receives interpretations from such special staff officers as the chemical officer (toxic chemical interpretations and interpretations relative to fallout predictions and travel of fallout clouds), the aviation officer, and the Staff Weather Officer. The weather information that he transmits to the command must be presented in its most usable form, with the operational aspects of the data indicated whenever applicable.

57. Effects on Military Operations

a. Temperature.

- (1) Periods of freezing temperatures will increase the trafficability of some soils, while with others it may create ice sheets on roads, making movement more difficult. Thawing temperatures may make frozen soils difficult to traverse and may damage roads with poor foundations. The ability of projectiles to penetrate the earth is decreased by frozen soil, but freezing increases the casualty effect of contact-fuzed shells. Melting snows may cause floods and result in avalanches in mountain areas.
- (2) Temperature inversions create an exception to the normal decrease in temperature that occurs with increases in altitude. In a temperature inversion, the air nearest the ground is colder than the overlying air. The lower air remains stable. Dust and smoke remain near the ground, reducing visibility and air purity. Inversion conditions are favorable to either enemy or friendly employment of toxic chemical or biological agents. Radar beams may also be refracted or ducted due to inversions.
- (3) In selecting sites to provide protection against low temperatures in the northern hemisphere, preference should be given

to the southwesterly slopes of hills and mountains, where the temperature usually is higher than on other slopes. Cold air flows downslope and remains pocketed in inclosed drainage areas or is dummed by forests or other barriers. These cold air pockets have the lowest temperature of the terrain, and often are characterized by freezing or fog when adjacent areas are frost-free or clear. Such cold air drainage areas should not be selected for troop bivouacs or for such facilities as motor pools and hospitals. In hot climates, caution is required in utilizing cold air pockets, since they are likely areas for the formation of ground fog and excessive humidity. Areas susceptible to cold air drainage can be readily located by ground reconnaissance or from topographic maps by visualizing the flow of cold and dense air over the terrain. In general, concave land surfaces facilitate the accumulation of cold air, while convex surfaces favor drainage of air from the surface. Toxic chemical and biological aerosols also tend to collect in depressions and low places.

- (4) In areas where heating is required, careful selection of the terrain in locating bivouacs and other installations will save fuel. If temperature data are available for various possible sites, or can be estimated by altitude factors and terrain configuration, fuel requirements may be closely ascertained.
- (5) Toxic chemical agents vaporize more rapidly in high ambient temperatures than in low ambient temperatures. The effects of weather on toxic chemical and biological agents, and on radiological contamination, are discussed in FM 3-5 and TM 3-240.
- (6) Temperature has no significant effects upon the intensity of blast or the thermal radiation of nuclear weapons.

b. Winds.

- (1) In arid or semiarid areas, strong winds frequently raise large clouds of dust and sand which greatly reduce observation. Similar effects result in snow-covered regions, where blowing snow may reduce visibility over wide areas. Observation aircraft may be grounded entirely during such periods.
- (2) The speed and direction of the wind are prime considerations in the contamination of areas by toxic chemical agents, biological agents, and radiological fallout. Winds of 3 to 10 miles per hour provide the most favorable conditions for the employment of contaminating agents. Winds below or above that range cause a loss of effectiveness in the use of gas, smoke, chemicals, radioactive clouds and mists. The direction of the wind must be considered for the protection of friendly troops. In areas characterized by great turbu-

lence and variable winds the use of contaminating agents is highly dangerous.

- (3) Winds tend to deflect projectiles from their normal paths, particularly when they are fired at long ranges. The effect that wind will have on a projectile increases with an increase in the velocity of the wind and the size of the projectile. To secure accuracy in artillery fires, there must be accurate, timely wind reports and predictions. Winds also reduce the efficiency of sound-ranging equipment.
- (4) Parachute landings are feasible in winds up to 15 miles per hour. At higher velocities, the wind tends to scatter troop concentrations, foul equipment, and increase the number of casualties from landing accidents. Strong winds also increase the time that parachutists must remain in the air, as well as the time required to secure equipment and prepare for combat after landing.
- (5) Strong winds hinder amphibious operations by creating high seas which will prevent landing craft from landing or retracting.
- (6) Wind speed and direction have no influence upon the blast or thermal radiation effects of nuclear weapons, nor upon the range of the initial nuclear radiation. Winds at all atmospheric levels are significant factors, however, in determining the location of radiological fallout resulting from the surface, subsurface or airburst of a nuclear weapon. Contaminated dirt and debris carried upon the column and cloud will be deposited downwind.
- (7) The effectiveness of toxic chemical and biological agent aerosols is influenced by the direction and speed of the wind. Such aerosols are dissipated rapidly in high winds. The use of toxic chemical agents in vapor form is most effective on clear or partially clear nights when the air usually is most stable.
- (8) Strong winds can damage radar antennas or even prevent use of the radar.

c. Humidity.

- (1) The effects of humidity upon ballistics are minor but important. The amount of water vapor in the air affects the trajectory of projectiles by the influence that it has upon air temperature and density. Humidity also has an effect upon the distance that sounds travel, thus affecting sound-ranging operations.
- (2) Humidity does not seriously decrease the effectiveness of most toxic agents and may increase the effectiveness of some, such as blister gas. The effectiveness of some biological

agent aerosols may tend to be increased by moisture in the air since living organisms are affected adversely by dry air and direct sunlight.

- (3) In the use of a screening smoke, a humidity of 90 percent will have twice the obscuring effect of a humidity of 40 percent. With this increase in relative humidity, only one-fourth of the amount of smoke-producing material need be used.
- (4) Humidity has no influence upon the blast effect or nuclear radiation of a nuclear weapon and no direct effect upon thermal radiation intensities. It will affect target vulnerability to a degree, because it will determine the moisture content of clothing, structures, equipment, and vegetation and their susceptibility to ignition. This effect is pronounced, however, only when a very high or very low relative humidity has prevailed over a long period.

d. Clouds.

- (1) Daytime cloudiness reduces the amount of heat received from the sun at the earth's surface, slowing down the drying of roads and affecting the trafficability of soils. Extensive night cloudiness prevents the loss of heat from the earth's surface due to radiational cooling and results in higher nighttime temperatures.
- (2) Cloudiness chiefly affects air operations by limiting aerial observation and reconnaissance. Dense clouds above the camera level may reduce light intensity to the point that photography becomes difficult or impossible. A high, thin layer of clouds, on the other hand, may eliminate ground shadows and thus improve the quality of aerial photographs. In cloudy areas, close combat air support may be restricted to aircraft equipped with suitable navigation instruments.
- (3) Low-lying clouds may be used to advantage by reflecting searchlight beams to illuminate the ground surface. Any considerable degree of night cloudiness reduces the amount of moonlight that reaches the ground. If the fullest utilization of twilight periods is desired, the extent of cloud cover must be considered.
- (4) Clouds have no influence upon the blast effect of nuclear weapons that are burst below them, nor do they affect nuclear radiation, but they may affect the intensity of thermal radiation reaching a target. If a weapon is burst above or within a continuous cloud layer over the target, a large portion or all of the thermal radiation may be attenuated, with a serious loss of effect. The amount of loss will depend upon the thickness and continuity of the cloud layer and the position of the burst with respect to it. If a weapon is burst below a

- (3) Precipitation, or the lack of it, has a major influence upon military operations.
- (a) Precipitation affects soil trafficability and hence cross-country movement. In areas of seasonal precipitation, the cross-country movement characteristics of an area may change drastically each season. Seasonal floods may swell or flood streams, making fording and bridging operations difficult or impossible.
 - (b) Snow and sleet hamper movement on roads in winter, often making them impassable in mountainous areas. The snow that accumulates in mountains during the winter months frequently affords a water supply throughout the year to lower, drier regions.
 - (c) Precipitation usually has an adverse effect on visibility and observation, although rain sometimes may wash excessive impurities from the air. Rain and snow aid concealment, and may facilitate surprise attacks. Operation of listening and sound-ranging posts is often limited by precipitation.
 - (d) Rain and snow normally reduce the effectiveness of toxic chemical and biological agents. Heavy or lasting rain washes away these agents and may neutralize them. Snow may cover liquid toxic agents so that little vapor or contamination hazard appears until the snow melts. Heavy precipitation will tend to dilute the concentration of biological agent aerosols.
 - (e) Precipitation may have an adverse effect upon communications, reducing the range of field wire circuits and producing radar "clutter" which tends to obscure target echoes.
- (4) Precipitation has a significant effect upon the blast effect of a nuclear weapon, but no effect upon initial nuclear radiation. It affects the range of thermal intensity to the degree that it reduces visibility. Buildings, equipment, debris, vegetation, and other normally flammable elements will require higher thermal intensities for ignition, and the spread of primary or secondary fires will be limited. Residual radiation may be affected. If the radioactive particles formed in an airburst descend into rain-bearing clouds, the nuclear cloud (if it does not rise above the rain-bearing clouds) will become so mixed with the rain cloud that it will become an integral part of the rain-producing system. The radioactive material will be deposited with the rain over a large area. Heavy rain over an area would wash away some of the material from a contaminating burst, either air, surface or

subsurface, possibly concentrating it in other areas where there are watercourses, low ground, drainage system, or flat undrained areas.

Section II. CLIMATE

58. General

a. Climate (fig. 14) refers to the seasonal variation and pattern of temperature, precipitation, humidity, winds, and air pressure. It is a composite of the day-to-day weather at a given place or area over a long period of time.

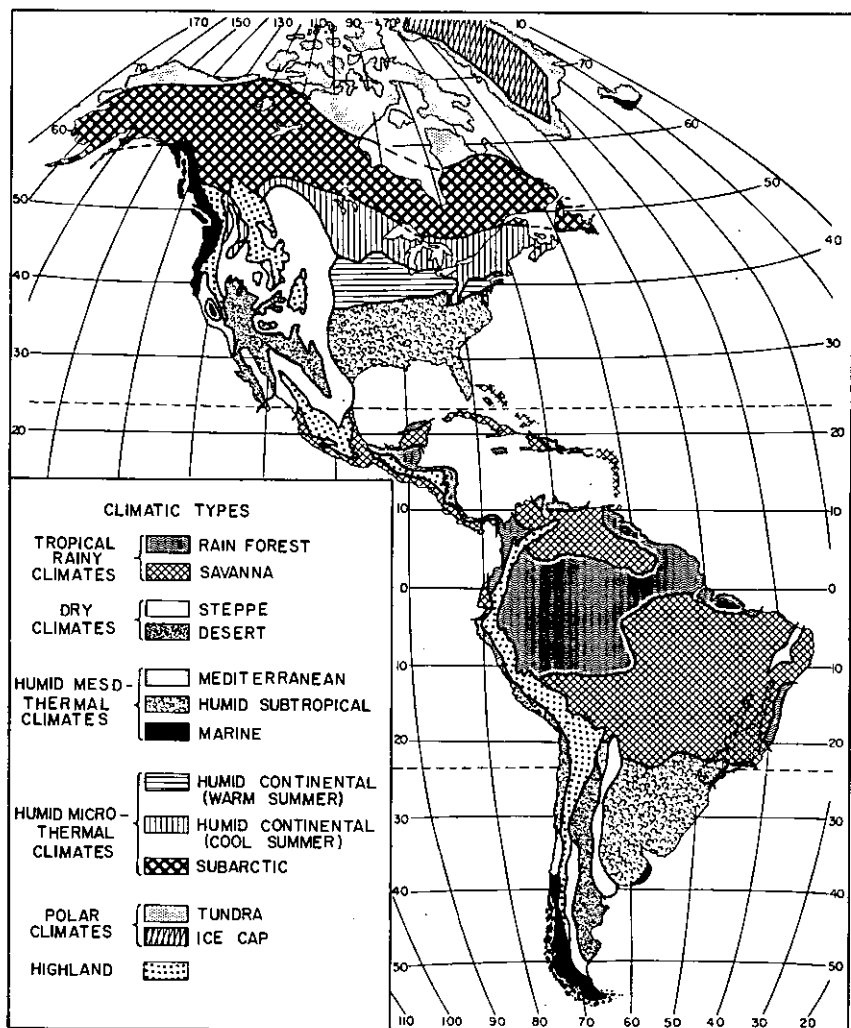


Figure 14. Major climate regions.

b. The strength and direction of winds, amount of precipitation, and average temperatures (figs. 15 and 16) that will prevail in a particular area can be predicted with reasonable accuracy, based upon statistics compiled for previous years. These climatic elements may be described by graphs or charts or in terms of mean, maximum, or minimum average values, absolute values, percent, or probabilities of occurrence.

c. While the heat energy transmitted by the sun to the earth is the dominant factor in weather and climate, terrain features also exert an important influence. In many regions, terrain has a major effect upon the climate. This is the case, for example, where high mountains block the movement of air masses and act as climatic divides. Another important example of terrain control is the difference in climate between land and ocean areas, where the land has higher summer temperatures and lower winter temperatures than the adjacent body of water.

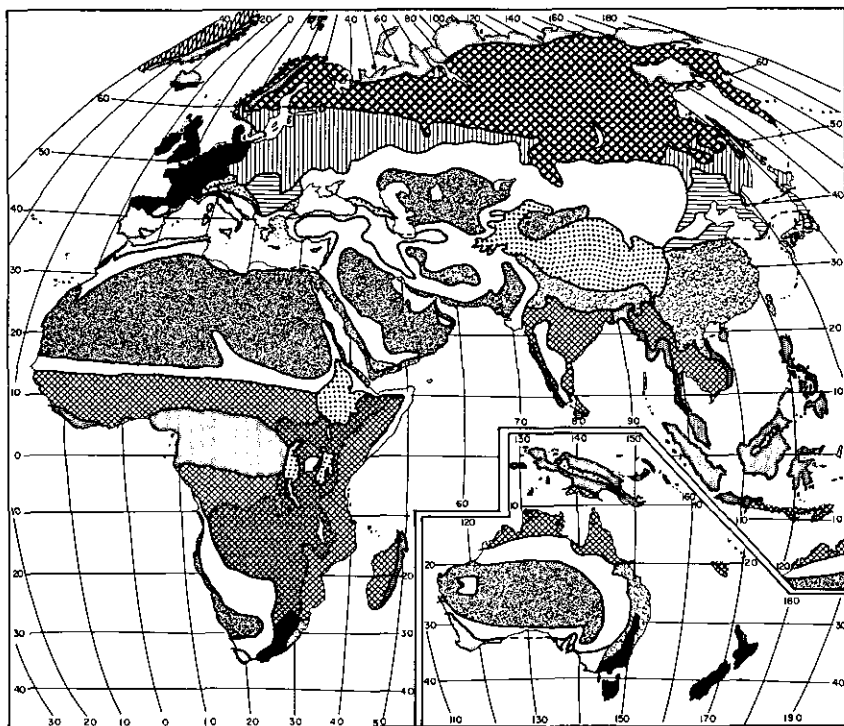


Figure 14—Continued.

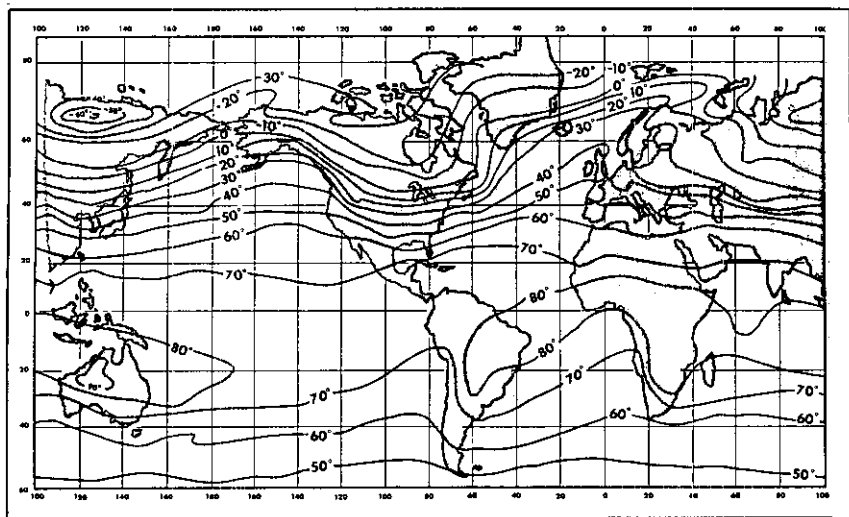


Figure 15. World temperatures in January.

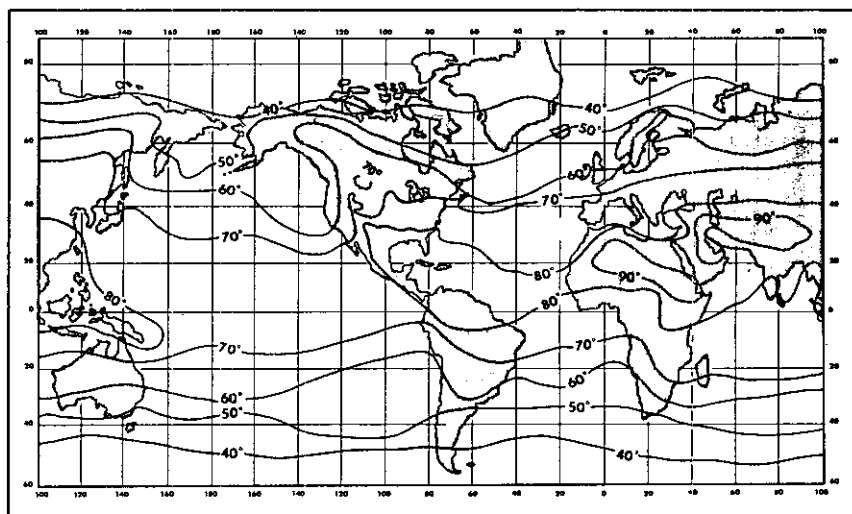


Figure 16. World temperatures in July.

d. Local terrain influences may also be highly significant in military operations. The ground configuration often produces fogs, winds, and other conditions in a predictable pattern. Information about these local phenomena frequently can be obtained only by the analysis of topographic maps, ground reconnaissance, and the interrogation of inhabitants.

e. The influence of climate on the growth of plants is a predominant factor in their distribution, and the relation between soil formation and climate is so close that the pattern displayed by a soil map will provide an indication of the climatic conditions.

59. Tropical Rainy Climates

a. Rain Forest Climate.

- (1) The tropical rain forest climate occurs in a belt generally extending from 5° to 8° on either side of the Equator. In some regions, such as the Amazon Basin and the coast of Zanzibar, the air is always hot and damp, there are frequent torrential rains of short duration, and the winds are feeble or absent for long periods of time. A variation of this climatic type exists on windward coasts between latitudes of 5° and 25° , where easterly sea breezes blow almost constantly over hills or mountains. The cooling of these winds as they rise over the barriers produces an extremely heavy rainfall. This occurs, for example, in portions of Formosa, Hawaii, the Philippines, the eastern coasts of Central America, Brazil, Madagascar, Indochina, and most of the islands in the southern Pacific Ocean.
- (2) In this type of climate, the rays of the sun are nearly vertical most of the time, so that days and nights are practically equal in length throughout the year. Night temperatures usually are a few degrees lower than daytime temperatures. There are no clearly marked seasons. Relative humidity is high at all times, and cloudy weather prevails. There are heavy rains on at least 4 or 5 days each week, with an increase in the amount of rainfall during periods when the sun is directly over the Equator. The rains are torrential, often accompanied by thunder and lightning. Ordinarily the rain begins in the afternoon, when the heated air is rising most rapidly, and ends before nightfall, although occasionally a light rain will continue into the night.

b. Savanna Climate.

- (1) The tropical savanna climate occurs generally in the regions from 5° to 15° on either side of the Equator, between the dry climates and the tropical rain forest regions. Instead of the dense forests typical of the tropical rain forest climate, the savanna regions have more open forests and large areas covered with tall grasses.
- (2) Savanna regions have high temperatures, with annual ranges (difference between mean temperature of the warmest and coldest months of the year) varying between 5° and 15° F. The total amount of rainfall is less than that of the tropical rain forest climate. There are distinct wet and dry seasons, and the rainy season begins and ends with severe squall winds and violent thunderstorms. During the rainy season, periods of intensely hot sunshine also alternate with brief, violent deluges of rain. The amount of rainfall varies considerably,

so that there are years of drought and years of flood. In the dry season the weather resembles that of desert regions, with very low humidity. Trees lose their leaves, rivers reach their lowest levels, and the soil becomes hard and cracked. Visibility is greatly reduced by dust and the smoke from grass fires, which readily ignite from a small spark and spread rapidly over vast areas.

c. Monsoons. In certain parts of southern and southeastern Asia, particularly in India, Burma, and Indochina, the climate is greatly influenced by monsoon winds. The wet and dry seasons coincide respectively with the onshore and offshore winds.

60. Dry Climates

a. Dry Climates.

- (1) Dry climates are those in which the potential evaporation exceeds the precipitation. The dry climates are located on the leeward interior portions of continents. There are two subdivisions: the arid or desert type, and the semiarid or steppe type. The steppe is a transitional region surrounding the desert and separating it from the humid regions.
- (2) The dry climates are characterized by extreme seasonal temperatures with large annual ranges. Daily ranges also are high. Humidity is relatively low, averaging from 12 to 30 percent around the middle of the day. Generally the skies are clear and cloudless. Because vegetation is meager, the barren surface of the dry earth becomes very hot during the day and cools rapidly at night. The vegetation offers little friction to the moving air, and accordingly, strong, persistent winds are typical of desert regions.

b. Low-Latitude Desert Climates. These occur in the vicinity of 20° to 25° north or south, with the average positions of their extreme margins at approximately 15° and 30° . The Sahara and Australian Deserts are typical examples of this type of climate. These desert regions have occasional small and erratic rains which come in violent torrents that may turn dry streambeds (wadis) into raging torrents. Often there will be no rainfall for several years. The skies are almost always clear and cloudless.

c. Low-Latitude Steppes. These are semiarid, having a short period of rain-bearing winds and storms each year. Precipitation, however, is meager and erratic. Steppe regions on the poleward sides of deserts have almost all their annual rainfall in the cool season. Those adjoining savannas on the equatorward sides of deserts generally have a brief period of relatively heavy rains during the time when the sun is highest.

d. Middle-Latitude Dry Climates. These occur within the deep interiors of continents, in the regions surrounded by mountains or plateaus that block the humid maritime air masses. Rainfall is meager and undependable, as in the low-latitude deserts, but there is also a season of severe cold. In winter there may be a small amount of snow, frequently accompanied by strong winds. The temperature and weather characteristics are similar to those of humid continental plateaus in comparable latitudes, except that there is less rainfall. Iran provides a typical example of this climate.

e. Middle-Latitude Desert Climate. This climate is characterized by lower temperatures and greater precipitation than low-latitude desert climates. This climate occurs in the basinlike, low-altitude areas, surrounded by highland rims, that exist in some continental interiors. The Gobi Desert and the desert of central Iran have this type of climate. Summer temperatures are high. Middle-latitude steppes occupy intermediate locations between deserts and humid climates. They have small amounts of rainfall, which is usually unpredictable in amount or time of occurrence.

61. Humid Mesothermal Climates

a. Humid Mesothermal Climates. These are characterized by moderate temperatures that occur in a seasonal rhythm. There are three general types: Mediterranean, marine west coast, and humid subtropical.

b. Mediterranean Climate.

- (1) This climate has hot, dry summers and mild winters, during which most of the annual precipitation occurs. Annual rainfall usually ranges from 15 to 25 inches. In the winter months, the average temperature is between 40° to 50° F.; in summer, it ranges from 70° to 80° F. This type of climate occurs in five regions—the borderlands of the Mediterranean Sea, central and coastal Southern California, central Chile, the southern tip of South Africa, and parts of southern Australia.
- (2) Coastal areas often have a modified type of Mediterranean climate, with cool summers due to the offshore ocean currents. There is apt to be a cool daily breeze along the seacoast and for a short distance inland. Relative humidity is high. Fogs are frequent, but usually are dissipated by the heat of the sun in the early morning hours. Winters are frost-free and mild, and the annual change in temperature is small.
- (3) Summer days in Mediterranean climates are warm, with bright sunshine, low relative humidity, and nearly cloudless skies. Daily weather becomes erratic and unpredictable in autumn. The winds are less regular and there is occasional

rain. Temperatures remain relatively high. Winters are mild and warm, with occasional light frosts and moderate showers.

c. Humid Subtropical Climate.

- (1) This climate occurs in regions located on the eastern sides of continents, generally from about latitude 25° poleward (north or south) to 35° or 40° . This type of climate is found, for example, in the American Gulf States. Temperatures are similar to those of the Mediterranean climate, with less contrast between regions on the coast and those located inland. Rainfall ranges from 30 to 65 inches a year.
- (2) In the summer, humidity is high, temperatures average from 75° to 80° F., and there are frequent thundershowers. Nights are hot and sultry. There is no drought season, but normally there is less rain in winter than in summer. Thunderstorms are frequent in areas of low elevation, and severe tropical cyclones occur in the late summer and early fall.
- (3) Winters are relatively mild in this type climate. Temperatures in the cool months average between 40° and 55° F. Usually the midday temperature is around 55° to 60° F. and the night temperature, from 35° to 45° F. The high humidity, however, makes the nights chilly and uncomfortable. Snow may fall occasionally, but it does not remain for more than 2 or 3 days. Daytime temperatures may be raised above 60° or 70° F. by the arrival of a tropical air mass, then be reduced by a subsequent polar wind as much as 30° F. in 24 hours, resulting in a severe freeze.

d. Marine West Coast Climate.

- (1) This climate occurs on the western or windward sides of continents, poleward from about 40° latitude. This type of climate results from onshore westerly winds that blow over the land from adjoining oceans. It borders the Mediterranean type on its equatorward margins, extends into the higher middle latitudes, and ends at the subarctic or tundra climate. Where mountains are closely parallel to the west coast, as in Scandinavia, this type of climate is confined to a relatively narrow region on the seaward side of the highlands. In parts of western Europe, where there are extensive lowlands, the effects of the ocean conditions have an influence on the climate for many miles inland.
- (2) In the marine west coast type of climate, summers are cool and sunny, with occasional hot days but no severe or prolonged heat waves. Rainfall is fairly abundant. Winters are mild, particularly in western Europe, where a great mass of warm water known as the North Atlantic Drift (also

known as the Gulf Stream) lies offshore. Cloudy skies and a humid atmosphere are prevalent. There are frequent severe frosts. The midday temperatures of most winter days are relatively high. During unusually cold periods, temperatures may remain below freezing for several days. The winter season is marked by severe storms, fogs, and mist.

- (3) Where the western coasts are bordered by mountain ranges, as in Norway and Chile, precipitation may reach a total of 100 to 150 inches a year. In areas consisting predominantly of lowlands, rainfall usually averages from 20 to 35 inches a year and may fall steadily for several days at a time. In mountainous regions, such as the Cascade Range or the Scandinavian Highlands, snowfall is very heavy. The marine west coast climate is cloudy, and has mist or fog for at least 40 days a year.

62. Humid Microthermal Climates

a. General. The humid microthermal type of climate occurs in the Northern Hemisphere northward from the subtropical climatic regions and in leeward interior locations. It has colder winters than the mesothermal type, with larger annual changes of temperature, longer frost seasons and snow cover that lasts for considerable periods. *Humid continental* and *subarctic* are the principal types of microthermal climate.

b. Humid Continental Climates.

- (1) These climates border the marine west coast climatic regions. Where there are mountain barriers, as in North America, the change between the two types of climate is abrupt, but it is very gradual where there are no barriers, as in the lowlands of western Europe. Seasonal differences are extreme, with very cold winters and warm summers. Along the seaboard, the summer heat is oppressive and sultry because of the higher humidity, and the winter cold is more raw and penetrating than in the drier interior regions.
- (2) Along the interior margins, humid continental climates border upon the dry climates and have subhumid characteristics. The prairies of North America and interior Eurasia are examples of such climatic regions. In these areas, the maximum rainfall usually occurs in late spring and early summer, rather than at the time of greatest heat. In winter, regions with a humid continental type of climate have a permanent snow cover that lasts from a few weeks to several months. Summer rains usually occur in sharp showers accompanied by thunder and lightning.

- (3) Winter in the prairie regions is characterized by violent blizzards, known as *burans* in Russia. A blizzard is marked by violent gales, drifting snow, and extreme cold. Although there may be no precipitation falling, the air is filled to a height of several hundred feet by swirling masses of dry, finely pulverized snow. Afternoon thunderstorms frequently occur during summer in prairie regions.
- (4) Regions on the southern margins of microthermal climates have long, hot, and humid summers lasting from 150 to 200 days between the periods of frost. Winters are cold, with frequent intervals of mild, rainy weather.
- (5) Winter is the dominant season on the poleward side of regions with this type of climate. Summers are relatively short, usually comprising a period of about five months. Temperature changes of as much as 40° F. in 24 hours are common in spring and autumn.

c. Subarctic Climate.

- (1) This climate occurs in latitudes of 50° to 60° in the Northern Hemisphere. The European subarctic, or taiga, extends from Finland and Sweden to the Pacific coast of Siberia. In North America, the subarctic stretches from Alaska to Labrador and Newfoundland. Long, extremely cold winters and very brief summers characterize this type of climate. Winter quickly follows summer, with only a short period of autumn intervening. A large part of the taiga regions are frozen to a considerable depth, with only a few feet of the upper part thawing out in the summer.
- (2) There is little precipitation in subarctic regions. No more than 15 inches a year falls over the greater part of the Siberian taiga, and in most of subarctic Canada the precipitation is less than 20 inches annually. Precipitation exceeds 20 inches chiefly along the oceanic margins of Eurasia and North America.

63. Polar Climates

a. Location, Temperature, and Precipitation.

- (1) The poleward limit of forest growth usually is considered the dividing line between polar climates and those of intermediate latitudes. This coincides generally with a line (isotherm) connecting points having a temperature of 50° F. for the warmest month. A mean annual temperature of 32° F. or below is also a distinguishing feature of polar climates.
- (2) In the Southern Hemisphere, the only large land area with a polar climate is the Antarctic Continent. In the Northern Hemisphere, this climatic region includes the Arctic Sea, the borderlands of Eurasia and North America, with the island

groups that are north of these continents, and ice-covered Greenland. The Arctic is almost a landlocked sea, while the Antarctic is a seagirt land. As a result, there are important climatic differences between the two regions. The climate has fewer wide variations in the Antarctic because it is a single land mass completely surrounded by oceans with a uniform temperature.

- (3) Arctic climates have the lowest mean annual and summer temperatures on earth. Although the sun remains above the horizon for 6 months of the year, the rays are too oblique to raise the temperature significantly. Much of the energy from the sun is reflected by snow and ice, and is consumed in melting the snow cover and evaporating the water. As a result neither the land surface nor the air adjacent to it becomes warm.
- (4) Precipitation averages less than 10 inches a year over large parts of the polar land areas. Because of the low evaporation and small amount of melting, permanent ice fields several thousand feet thick have accumulated on Greenland and the Antarctic Continent.

b. Tundra Climate.

- (1) Polar climates usually are divided into two types—*icecap* and *tundra*. *Icecap* climates are those where the average temperature of all months is below 32° F., vegetation will not grow, and a permanent snow-and-ice cover prevails (figs. 17 and 18). When one or more months in the warm season have an average temperature above 32° F. but below 50° F., the ground is free from snow for a short period and



Figure 17. Arctic terrain.



Figure 18. Arctic icecap, showing warm-weather drainage.

low sparse vegetation is possible. This climate is designated as *tundra*.

- (2) Tundra climate is less rigorous than that of the icecap regions. The warmest month isotherms of 50° F. on the equatorward side and 32° F. on the poleward side are considered to be the boundaries. Over land areas, tundra climate is confined largely to the Northern Hemisphere. Ocean prevails in those Antarctic areas where the tundra climate normally would be found. Summers warm enough to develop a tundra climate occur only in the most northerly fringes of the Antarctic and on certain small islands of the region. The most extensive tundra areas are on the Arctic Sea margins of Eurasia and North America.
- (3) Long, cold winters and brief, cool summers characterize the tundra climate. Average temperatures usually are above freezing only for from 2 to 4 months of the year, and killing frosts may occur at any time. Fog is prevalent along the coast, frequently lasting for days at a time. Snow cover disappears for one or two months during the summer season, and the lakes usually are free from ice. Drainage is poor because of the permafrost, resulting in many bogs and swamps.
- (4) Summer temperatures do not differ greatly in the various tundra regions. There is, however, a considerable variation

in winter temperatures. Average temperatures in the Arctic coastal areas of Siberia average about -35° to -40° F. in January and February, with even lower temperatures inland. Along the Arctic borders of North America, the temperature for comparable periods is higher, and winters are less severe.

- (5) Annual precipitation normally does not exceed 10 to 12 inches in the tundra regions, although larger amounts are received in parts of eastern Canada, particularly in Labrador. Usually the most precipitation occurs in summer and autumn, the warmest seasons. Most of it is in the form of rain, with occasional snow. The winter snow is dry and powdery, forming a compact cover. Often it is accompanied by strong blizzard winds which pile up the snow on the lee sides of hills and in depressions, sweeping exposed surfaces bare. There is no vegetation to break the force of the wind and to hold the snow cover.

c. Icecap Climate. This climate characterizes the permanent continental ice sheets of Greenland and Antarctica and the ocean in the vicinity of the North Pole. The average winter-month temperatures range from -35° to -45° F. Storms or violent winds do not occur as frequently in the inner portions of the icecaps as in other climatic regions, but in some marginal areas there are extreme gales caused by the precipitous descent of cold air from the continental ice plateau.

64. Climatic Studies

a. Climatic studies are based upon the records of past weather in a given area compiled over a long period of time. They are used in preliminary planning to provide an estimate of the climatic averages that may be expected during the period of the proposed operations. These studies are of particular value to the Quartermaster Corps, Ordnance Corps, Transportation Corps, and other services in developing new equipment and in anticipating the logistical problems that may arise in a projected campaign.

b. Special climatic studies may be prepared covering winds, rainfall, tides, sea conditions, state of ground, and similar aspects of a specified area. Such studies have been made, for example, to provide data for use in determining—

- (1) Location of camps, training areas, depots, and landing fields.
- (2) Coastal areas most suitable for amphibious operations.
- (3) Operations of aircraft over certain mountainous areas.
- (4) Smoke behavior in specified localities.
- (5) Seasonal fuel requirements by weight, quantity, and type.

c. Requests for climatic studies should be made as far in advance as possible, and should provide all pertinent information, including—

- (1) Nature of mission.
- (2) Geographical area and time.
- (3) Operational limits.
- (4) Degree of flexibility permitted in accomplishing the directive.
- (5) Recommended form of presentation.

Section III. OPERATIONAL ASPECTS OF EXTREME CLIMATES

65. Desert Regions

a. Weather.

- (1) High temperatures are normal in desert areas, the summer maximum may reach 120° to 130° F. The variation between day and night temperatures is great, the temperature often dropping below the freezing point in winter. These sudden changes in temperature often give rise to winds of hurricane force that carry large quantities of dust and sand. Under these conditions, visibility is very poor and movement may be impossible.
- (2) Rain is infrequent in desert regions, usually averaging less than 10 inches a year, but it may come in sudden downpours. Water sources are few, and frequently are polluted and brackish. Usually water for military forces must be transported by tank truck, rail, or pipeline from sources outside the desert area.
- (3) Winds blow almost constantly in the desert, frequently limiting the use of smoke and other chemical weapons. Minefields may be made useless by the blowing dust and sand. The wind either blows away the sand, exposing the mines, or deposits large quantities of it on the minefield, preventing detonation of the mines. In heavy dust and sandstorms, the operations of mechanized units are similar to those conducted at night.

b. Natural Features.

- (1) There are few landmarks in a sandy desert region, so that navigation methods must be used in movement. The most prominent features are the huge dunes created by sandstorms (fig. 19). Usually the surface of a sand dune is packed firmly by the wind for a depth of about 2 inches. This surface will support considerable weight, but detours may be necessary because many of the dunes are high, with steep slopes. Areas of loose sand impede movement on foot or by wheeled vehicles. Tracked vehicles are able to operate in

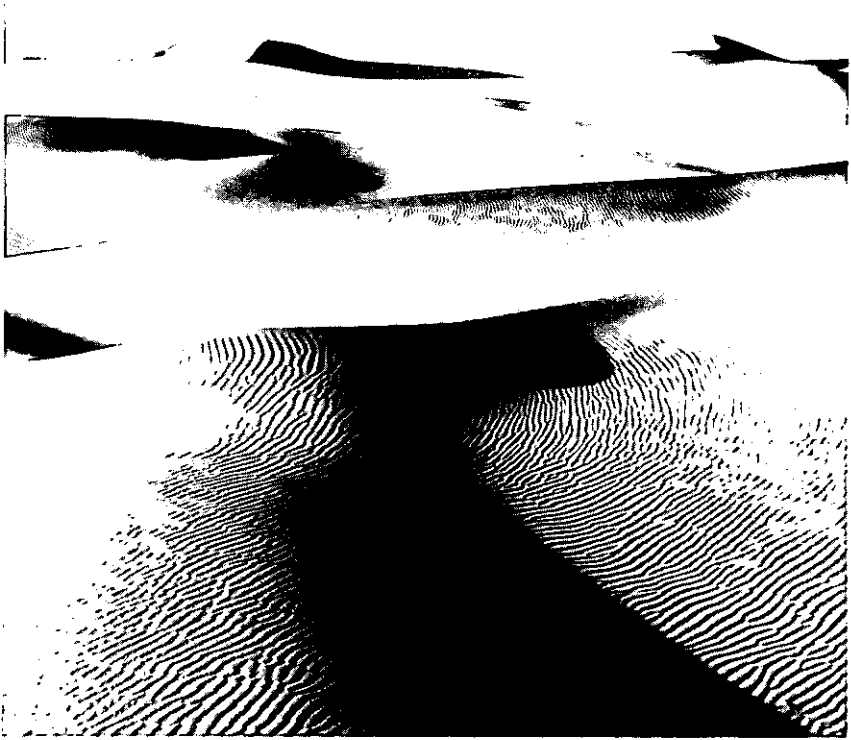


Figure 19. Sand dunes (Death Valley, Nevada).

shallow sand. In flat, hard-surfaced areas, roads and trails are not necessary and all types of vehicles can move cross-country.

- (2) Salt marshes, dry lakes, and wadis (dry streambeds) occur along coastal areas or inland in depressions. Wadis and dry lakes are impassable when wet and contain a powdery silt when they are dry which may cause vehicles to bog down.

c. Manmade Features.

- (1) Well-defined roads are scarce in desert regions, although there usually are trails between water sources. Occasionally flash floods may cut the routes for short periods of time. Dust and sandstorms may prevent traffic through lack of visibility and maintenance difficulties. A surfaced main supply route is essential and usually must be constructed. Road location is difficult and time-consuming, requiring extensive map study and area reconnaissance.
- (2) Buildings must be strong enough to withstand the frequent high winds and constructed tightly to reduce the infiltration of blowing sand and dust.

- (3) Field fortifications in sand require adequate strengthening, with a maximum use of sandbags. In rocky deserts, field works can be installed only with great difficulty. Field fortifications are easy to dig in sandy deserts, but they must be revetted, and may be filled quickly with drifting sand.

d. Military Aspects.

(1) *Observation.*

- (a) The brilliant sunlight of desert areas reflected from the light-colored ground surface creates a strong glare. An observer with the sun to his back may see well, but the glare greatly reduces visibility when he faces toward the sun. He loses his depth perception and will confuse objects which are in shadows or haze. On hot days, a shimmering haze may nullify ground observation at ranges of 500 yards or less, depending on local conditions.
 - (b) An optical phenomenon encountered in desert regions is the *mirage*, an effect produced by a stratum of hot air of varying density across which the observer sees reflections, usually inverted, of some distant object or objects. These occur frequently in summer and are evident in a wide arc which increases as the sun becomes higher in the sky. The effect of the mirage generally is to magnify objects, particularly in the vertical dimension. This has an adverse effect upon observation, making it particularly difficult to identify vehicles.
 - (c) Distances are deceptive in deserts, and usually are underestimated. Shadows on the light-colored terrain can be seen for miles but tend to distort distant objects.
 - (d) Moonlight in desert areas is much brighter than in other regions. Nights usually are very clear, the haze and glare being eliminated. Observation at night may be better than during some periods of the day.
 - (e) In open terrain, sound- and flash-ranging are particularly effective. Artillery observers, however, may find few positions that will allow a commanding view of the terrain.
- (2) *Field of fire.* The ability of a weapon to fire effectively in the desert usually is limited only by the range of the weapon and the ability of the observer to adjust fire. There is little vegetation or relief to mask weapons.
 - (3) *Concealment and cover.* Cover from enemy fire may be afforded by sand dunes, hills, and other irregularities in the desert terrain. Concealment is hard to obtain, since the vegetation is sparse. Camouflage is used more extensively in desert areas than in normal terrain, and reliance must be placed upon artificial means, since natural camouflage ma-

materials are lacking. Camouflage from air or ground observation is extremely difficult to obtain. The movement of troops during daylight is greatly restricted due to the lack of concealment and cover from air attack. Troops must be widely dispersed.

- (4) *Obstacles.* There are relatively few major obstacles to movement in most desert regions. Although the road net is limited, cross-country movement may be good, varying with the type of surface materials.
- (5) *Key terrain features.* In desert operations, terrain features usually are not major objectives, since the possession of a particular piece of ground seldom contributes materially to the destruction of the enemy force. Oases and other water sources are always critical, however, because an adequate water supply is the fundamental requirement of all military operations conducted in arid or semiarid regions.
- (6) *Nuclear weapons.* The ease of dispersion in desert areas ordinarily does not result in a concentration of troops that will provide for profitable employment of nuclear weapons. Suitable targets are provided, however, by airfields, communication centers, and supply installations.
- (7) *Toxic chemical and biological agents.* Two characteristics of desert regions which affect the employment of toxic chemical agents are the sparseness of vegetation and the extreme variations in ambient temperature. Opportunities for extensive use of toxic chemical agents generally are limited. Agents present storage problems because of the wide temperature ranges and the extreme lapse conditions existing during the day require high ammunition expenditures. Effective use of toxic chemical agents usually is limited to night. The direct sunlight and dry air which characterize desert regions may present unfavorable environmental conditions for some biological agent aerosols.
- (8) *Screening smokes.* Under desert conditions when the winds are still, large-area smoke screening is of considerable importance because of the normal lack of adequate natural concealment and cover.

66. Tropical Regions

a. Weather. Excessive heat and humidity characterize tropical regions throughout the year. In the rain forest type of climate, there is little seasonal variation in temperature. The weather is marked by sudden changes, with torrential rains that end abruptly to be followed at once by bright sunshine. Humidity tends to remain high because the vegetation checks evaporation. Although monsoon areas have a

dry season, the total rainfall is so great that rain forest vegetation is dominant. High temperatures prevail in the tropical savanna regions, which have distinct wet and dry seasons. In these areas, rain forest conditions exist in the wet season, and desert conditions in the dry season.

b. Natural Features.

- (1) Military operations in tropical regions are influenced chiefly by the rain forest vegetation. This comprises a dense growth of intermingled trees, vines, and giant ferns known as the *jungle*. Terrain covered by the jungle varies from mountain ranges to low, swampy plains. In Southeast Asia, the Pacific Islands, and parts of Latin America, the jungle covers irregular terrain of nonvolcanic and volcanic origin. Other jungle areas, such as those in central Africa and South America, generally are low and level. Jungle terrain also may present a combination of these conditions, with a flat, swampy, densely forested belt near the sea that is interspersed inland by grasslands, foothills, and high mountains, with occasional cleared and cultivated areas.
- (2) The coastal portions of jungle areas are characterized by mangrove swamps or by open beaches lined with bamboo or coconut groves. Beyond the shoreline there may be paddy fields or pineapple, coconut, sugar cane, or rubber plantations. Between these and the jungle there may be low-lying foothills covered with brush or tall grass.
- (3) Streams are numerous in jungle areas. They are generally muddy and subject to sudden floods. In wet seasons an entire area of flat jungle may become a continuous swamp. Streams in mountainous areas that normally are shallow may become raging torrents shortly after a heavy rain.
- (4) The characteristics of jungle terrain and its effects upon military operations are discussed in FM 72-20.

c. Manmade Features.

- (1) There are few roads or trails in jungle areas. Usually roads must be constructed, and the use of these is limited to light trucks or light tracked vehicles. Except for coral in some coastal areas, there is a lack of materials suitable for road construction. The dense vegetation, unstable soils, and poor drainage make roadbuilding difficult. To establish and maintain a road net of even minimum standards calls for greater engineer effort than in other types of terrain. Navigable waterways often provide the most efficient routes of communication, although they are highly vulnerable to ambush.
- (2) Bridges suitable for military loads rarely exist in jungle regions. The construction of bridges is complicated by the

frequency and intensity of flash floods, the tendency of some jungle streams to shift their courses, and the rapid decay of wooden structural members. Engineers must be prepared to repair or replace bridges rapidly at short notice.

- (3) Towns and villages in jungle regions rarely provide suitable facilities for military installations. Usually settlements are avoided for hygienic reasons. Excellent anchorages may be found along many tropical coasts, but there are very few water terminals sufficiently developed to be of any value in military operations.

d. Observation.

- (1) In the jungle, the dense vegetation often limits observation to very short distances. Usually the canopy in a primary rain forest, which consists of a virgin growth of mature trees, is so thick that it cuts off most sunlight, and visibility is limited to 20 or 30 yards. Visibility may be limited to 5 yards or less in the secondary forest, which is composed of a second growth that develops when the original forest has been burned off or cut. Rain, clouds, and the steamy exhalation from wet areas also tend to reduce visibility. Because of the limited visibility and the lack of conspicuous landmarks, it is often difficult to locate a ground position from a map.
- (2) Camouflage from close ground observation is of the greatest importance in the jungle. In heavily forested areas, however, there is less need for artificial camouflage against air observation. Whenever possible, the natural overhead cover is preserved, since any break in the normally uniform tree canopy of the jungle is readily noticeable from the air.
- (3) Because observation is limited, tactical units must employ narrow frontages, reduced distances and intervals between elements, increased patrol activity, and a larger number of liaison parties than required in more open terrain.
- (4) The difficulties of observation greatly restrict the employment of supporting arms and weapons. Artillery forward observer teams usually cannot see the burst and must adjust fire by sound spotting and sound sensing methods. Data based on maps or photomaps can be used only to a very limited extent.

e. Fields of Fire. Since natural fields of fire generally are limited to 5 or 10 yards, lanes must be cleared. Where the undergrowth is heavy, several days of labor will be required to clear 100-yard fire lanes around a position. In order to avoid revealing weapon positions, a fire lane in jungle growth usually is in the form of a tunnel from 1 to 4 yards wide, with the overhanging foliage left intact.

f. Effectiveness of Weapons.

- (1) For jungle warfare, the most effective weapons are those that can be supplied easily with ammunition and are readily transportable over difficult terrain. Suitable weapons include mortars, machineguns, automatic rifles, and grenades.
- (2) Armored vehicles cannot move through heavy jungle unless routes have been previously prepared. Usually the movement of tanks is limited to beaches, coconut groves, grass fields, and improved trails. The principal value of tanks is in the use of their flamethrowers, direct-fire weapons, and crushing weight in the destruction of enemy bunkers and other field fortifications. Tanks are highly vulnerable to ambush and close-in attack in jungle terrain.
- (3) Because the heavy vegetation reduces the effective bursting radius of artillery shells, weapons of 105-mm or higher calibers must be employed to blast away jungle undergrowth and destroy enemy positions. Artillery pieces should be capable of high-angle fire and be drawn by tractors that can ford small streams. Engineer equipment must be available for the improvement of trails, construction of firing positions, and clearing of fields of fire. In some mountainous areas, only pack artillery may be practicable.
- (4) Air forces are effective in close tactical support of ground elements, but their utility for tactical bombing is less than in other types of terrain.

g. Concealment and Cover. Jungle growth provides concealment from air and ground observation and where it is dense, may furnish some cover from small arms fire. High grasses, such as kunai, provide concealment but readily reveal any movement through them. They provide no cover. The amount of cover given by slit trenches and other field fortifications is often limited by the high water table, which prevents excavating more than a few feet below the surface of the ground.

h. Movement.

- (1) Cross-country movement in the jungle is slow and difficult. Troops may have to cut their way through continuous thick undergrowth and tall grass, or make lengthy detours to avoid impassable swamps. On most jungle trails, troops must move in a column of files, and the average rate of movement rarely exceeds 1 mile per hour.
- (2) Usually foot movement may be made most easily on ridges, where the vegetation is more open and the better drainage results in less muddy surfaces. Except for small, fast streams with traversable beds, movement is poorest along the banks of rivers, because of the dense vegetation, mud, swamps, and tributary streams.

- (3) Even in comparatively dry weather, mud slows down vehicular traffic in the jungles. It may be necessary to supplement motorized transport by the use of pack animals and carrying parties.
- (4) Jungle roads and trails rapidly disappear unless they are in constant use. Accordingly, maps showing these features seldom are reliable. Air photographs of jungle terrain rarely reveal more than the treetops.

i. *Key Terrain Features.* In jungle areas, the key terrain features generally are those that provide control of trails, navigable waterways, and beaches suitable for amphibious landings. Possession of the edges of an area of high jungle growth provides observation and thus gives advantages similar to those of high ground in wooded areas or in the edges of woods in forest regions.

j. *Communications.* Visual signaling is seldom effective in the jungle because of the dense growth. The use of messengers is slow and may be hazardous. Wire circuits are hard to install and maintain. The range of radio sets may be greatly reduced by the vegetation, resulting in ranges from 40 to 70 percent less than those considered normal in open or lightly wooded terrain.

k. *Toxic Chemical and Biological Agents.* Both the weather and terrain conditions in jungle areas are favorable for the employment of chemical and biological agents. Where the overhead canopy is very dense, however, sprays from aircraft usually are only moderately effective against personnel. The large-scale use of defoliants will increase the fields of fire of weapons.

67. Arctic and Subarctic Regions

a. Weather.

- (1) Severe changes in weather are common in Arctic and subarctic regions. These changes include shifting periods of severe frosts, mild weather, sudden freezing, snowstorms, strong winds, and dense fogs. Reliable and timely weather forecasts are essential to guard against damage to equipment and installations and to gain any tactical advantages that may be possible by exploiting changes in weather conditions.
- (2) Arctic operations frequently are hindered by strong winds, which usually occur more often along the coast than in the interior. Wind speeds in excess of 80 miles per hour have been recorded at coastal stations. Winds blow continually, and in most areas there are no hills, mountains, or other natural barriers to provide protection. Blowing snow constitutes a serious hazard to flying operations. Winds of 10 to 15 miles per hour will raise the snow several feet off the ground, obscuring such surface objects as rocks and runway markers.

- (3) The short days and long nights of winter reduce the amount of daylight available for tactical operations and work activities. Nights often are bright because of the illumination of the moon, stars, Aurora Borealis, and reflections from the snow, so that night movements are possible. The short summer nights permit military operations through the 24-hour period.

b. Natural Features.

- (1) Following a heavy snowfall, landmarks and other objects become covered, making orientation difficult. Gullies and ditches are filled and obscured so that movement is made more hazardous.
- (2) The freezing of swamps and lakes may convert obstacles into avenues of approach for the enemy. Warmer temperatures in spring will create thaws and mud in the subarctic, causing rivers and streams to overflow. In mountainous or hilly country, landslides can be expected in the spring, as the result of boulders and smaller rock formations expanding from the warmth of the thawing temperatures.

c. Manmade Features.

- (1) In the subarctic, routes of communication and transportation are affected by every heavy snowfall. Unless there has been proper advance planning, traffic may come to a complete halt. Strong winds cause snowdrifts which block all traffic, requiring a constant clearing of routes, and transportation is slowed greatly by ice and sleet. To avoid these drifts, roads may be routed through woods, where drifts seldom occur, or along the crest of high ground where the snow usually is less deep.
- (2) In extremely cold temperatures, railroad operation is restricted. Blocked tracks and derailments are frequent; switches often are frozen; snow and rock slides, washouts, and frost heaving damage the lines; and the ice caused by water seepage must be cleared from tunnels before they can be used.
- (3) Excavation is difficult in either frozen or thawed ground. In frozen ground, handtools are ineffective. Explosives are effective, but they must be employed in quantities greater than those normally required in other types of terrain. Gravel is easier to excavate than soil, because it has better drainage and accordingly does not freeze as solidly. Foxholes, trenches, breastworks, and emplacements may be provided by digging into the snow or through it into the underlying ground. Snow trenches usually need revetting. In very deep snow, tunnels may be dug to provide concealment.

They furnish cover from small-arms fire, but do not give protection from artillery fires.

- (4) The spring thaws in subarctic climates must be considered when planning structures and fortifications. Bunkers, trenches, and other field fortifications must be designed and sited so as to insure good drainage. In the thawing period, roads in low-lying areas and bridges are apt to be washed out. Floating ice will destroy or damage bridges of temporary or improper construction. Runways and landing strips will require considerable maintenance. Airfields that have been improperly designed and constructed may become wholly inoperative for extended periods.

d. Observation.

- (1) Arctic air is exceptionally transparent, providing visibility over long distances. There is a lack of contrast between objects, however, particularly when they are covered by a layer of new snow. Observation in the Arctic is restricted chiefly by fog, blowing snow, and local smoke. The latter is a serious problem only in the vicinity of larger settlements, where it often accompanies the shallow radiation fogs of winter. A *radiation fog* results from the radiational cooling of air near the surface of the ground on calm, clear nights.
- (2) Depth perception is adversely affected by Arctic conditions, principally by the extremely clear, dry air, the lack of color differences, and the diffusing effect of light on the crystalline surface of the snow and ice. During the periods of long twilight, particularly when the sky is overcast, the horizon line may be visible, yet it may be impossible to judge the distance, height, or variations in height of hills and valleys. Even the height of objects, such as a high bank of snow along a road, only a few feet away cannot be determined. This phenomenon generally is termed *gray out*. A *white out* is similar, except that the effect on near objects is not so pronounced.
- (3) The amount of light reflected from a snow-covered surface is much greater than that reflected from a darker surface, and accordingly the sun provides greater illumination in the Arctic than in other regions. When the sun is shining, sufficient light is reflected from the snow almost to eliminate shadows except in polar areas where the shadows are quite long when the sun is shining. This causes a lack of contrast, making it difficult for the observer to distinguish the outlines of objects even at short distances. The landscape may appear as a featureless grayish-white field. Dark

mountains in the distance may be recognized, but a crevasse immediately in front of a mountain may be undetected because of the absence of contrast. It is possible to read a newspaper with the illumination from a full moon in the Arctic, and even the stars create considerable illumination of the surface. Only during periods of heavy overcast does the Arctic night approach the darkness of other regions. In latitudes north of 65° there are long periods of moonlight, and the moon may remain above the horizon for several days at a time.

- (4) A fog condition peculiar to the arctic climate is *ice fog*. This is composed of minute ice crystals instead of the water droplets of ordinary fog. Ice fog forms in very cold, still air in a shallow layer next to the ground. It will also form at temperatures of -50° to -60° F. and may continue as long as these temperatures persist. Where the smoke from building chimneys contributes water vapor to cold, still air, ice fog may form at temperatures as high as -20° F. During periods conducive to the formation of ice fog, each vehicle with a combustion engine leaves a trail of fog in its wake. Aircraft may cause so much ice fog that visibility will remain below minimum for considerable periods until the fog has drifted away. Sea fog also restricts observation in coastal areas.
- (5) When the temperature increases rather than decreases with height through a layer of air, it is termed an *inversion*. The strong temperature inversions present over the Arctic during winter cause several phenomena that affect observation. Sound tends to carry great distances. Light rays are bent as they pass through the inversion at low angles, often causing objects beyond the horizon to appear above it. This effect, termed *looming*, is a form of mirage.

e. Effectiveness of Weapons.

- (1) The fields of fire of automatic weapons are subject to the effects of wind and snow. Final protective line fires may be rendered ineffective by snow drifts.
- (2) Impact bursts of high trajectory light artillery, mortar, and hand grenade fires are rendered relatively ineffective by the cushioning effect of deep snow. Heavy artillery, however, remains highly effective. The employment of proximity or mechanically timed air bursts and overhead fire usually is advisable. Because of the lack of identifying objects and landmarks on snow-covered terrain, the adjustment of fire is difficult. Registration fire with air observation and by sound and flash is hampered, since the snow obscures projec-

tiles and bursts. A round bursting on impact in deep snow appears as a small white splash, making sensing extremely difficult. Because of the cushioning effects of the snow, mines may fail to be detonated by personnel or vehicles passing over them.

- (3) The clear air and snow cover characteristic of arctic and subarctic regions may increase the thermal radiation effect of nuclear detonations in flat terrain. Snow shelters will be vulnerable to blast effects. Heavy snow and hard-to-manuever terrain will slow troops in traversing areas contaminated by residual nuclear radiation. When used in deep snow, impact detonating chemical ammunition burns in the snow and the chemical agent tends to be smothered by the snow. Toxic chemical munitions produce less vapor concentration because of the low temperature and the smothering effect of the snow. On the other hand, low temperatures increase the persistency of toxic chemical agents in both vapor and liquid form. Decay of biological agents is not as rapid in arctic areas as it is in temperate or tropical areas. Area coverage capability is increased.

f. Concealment and Cover. The snow-covered terrain offers few features that provide adequate concealment and cover. Tracks in the snow are almost impossible to hide, and dirt on fresh snow can be observed at a great distance. Due to the high visibility, effective camouflage is difficult. Because of the difficulties of concealment, night movements are frequently advisable.

g. Obstacles.

- (1) During the winter months, the lakes, swamps, and rivers are frozen over and cannot be employed as natural obstacles.
- (2) Artificial obstacles may be devised by freezing large masses of snow or icecrete (a dense frozen moisture of water, sand, and sometimes, gravel) into desired shapes, or by icing deep drifts. Roadblocks may be made by icing a section of the road, preferably one which the enemy must approach on an upgrade. Tank traps may be devised by cutting the ice on a lake or river, then allowing it to refreeze slightly.

h. Movement.

- (1) Winter is generally the best time to travel in the Arctic and subarctic, since the lakes, streams, and muskeg areas are frozen over and blanketed with snow. Frozen rivers and waterways often become the best routes of advance and lines of communications during the winter months.
- (2) In general, most vehicles are immobilized in snow from 3 to 5 feet deep. Tracked vehicles, usually can move at low speeds in packed snow that is no more than 3 feet deep. After a

packed snow trail has been formed by the passage of several heavy vehicles, normal speeds may be maintained. The surface becomes compacted into a hard mass that is easily traversed. A thaw or the passage of a great many vehicles on a relatively warm day will melt the snow surface, resulting in a coating of glare ice. The road then becomes practically impassable to tracked vehicles unless ice cleats are installed on the tracks or the road is sanded.

- (3) Foot movements are slow in 20 inches of snow and impossible in snow that is more than 40 inches deep without the use of snowshoes and skis. Hard-packed snow however is not difficult for troops to negotiate. Infantry sometimes cannot take full advantage of artillery preparation because the troops are unable to move forward fast enough.
- (4) With reasonable care lakes and streams may be crossed by vehicles in winter. The ice first must be checked for thin spots, cracks, and pressure ridges.
- (5) During the spring thaws, movements in ice and snow across tundra are difficult and dangerous. Cross-country movement is practically impossible. After the snow cover has melted from the ground, both wheeled and tracked vehicles can move relatively freely on it as long as the surface remains frozen. This surface, comprising a layer of ground that thaws in the summer and freezes again in the winter, is termed the *active layer*. As soon as the active layer has melted, the tundra cannot support heavy concentrated loads and ordinary vehicles will bog down. Even special-purpose vehicles become roadbound during the thaw period and cannot move across the tundra.

CHAPTER 6

NATURAL TERRAIN FEATURES

Section I. GENERAL

68. General

a. Topography refers to the physical features, both natural and manmade, of the earth's surface. In terrain analysis, the following categories of topographical features are considered: relief, drainage, surface materials, vegetation, special physical phenomena, and man-made (cultural) features. Terrain refers to a consideration of topography in terms of military significance.

b. *Weathering* and *erosion* play a major role in shaping natural features. Weathering comprises the effects of the weather elements and erosion includes the action of running water, waves, moving ice and snow, and wind upon rock and soil (fig. 20).

c. *Landform* is the physical expression of the land surface.

- (1) The principal groups of landforms are plains, plateaus, hills, and mountains (fig. 21). Within each of these groups there are surface features of a smaller size, such as flat lowlands and valleys. Each type results from the kind and structure of underlying rock and from the interaction of earth processes in a region with given conditions of climate.
- (2) A complete study of a landform includes determination of its size, shape, arrangement, surface configuration, side-slope



Figure 20. Landforms caused by erosion in an arid climate (a) Pinnacle. (b) Butte (Grand Canyon, Arizona).

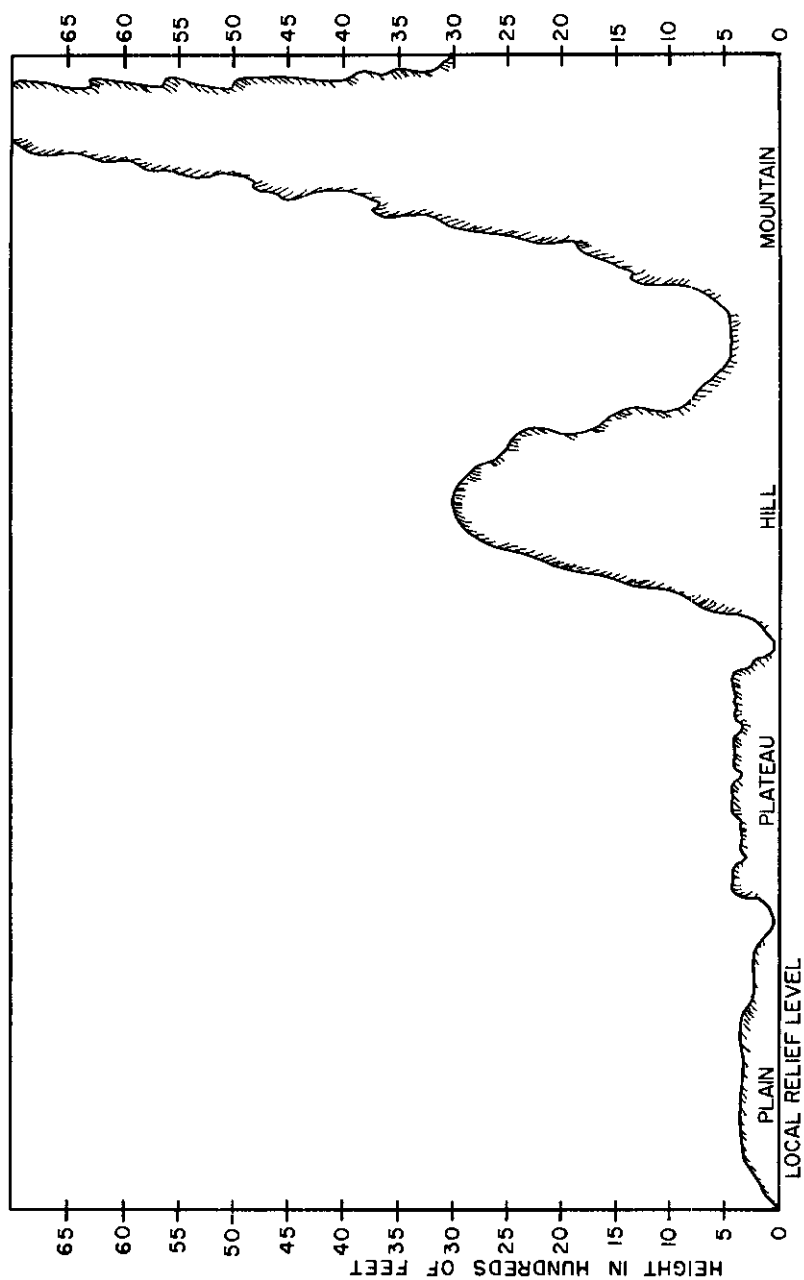


Figure 21. Relative elevations, major classes of landforms.

conditions, border conditions, and relationship to the surrounding area.

d. *Relief* refers to the irregularities of the land surface.

- (1) *Local relief* indicates the difference in elevation between the highest and lowest points in a limited area. The size of this area depends upon the purpose for which the surface is being considered. In terrain studies, it is usually one square mile.
- (2) *Relief features* are the individual forms of the land surface, such as hills or ridges.
- (3) *Major relief features* are plains, plateaus, hills, and mountains.
- (4) *Minor relief features* are described by various terms, depending largely upon local usage, and include—
 - (a) *High ground*—swells, knolls, mounds, knobs, hummocks, hillocks, spurs, ridges, buttes, mesas, and dunes.
 - (b) *Depressions*—gullies, draws, gulches, wadis, ravines, gorges, arroyos, canyons, and basins.
 - (c) *Breaks in high ground*—saddles, notches, cols, passes, cuts, and gaps.
 - (d) *Special features*—alluvial fans, talus slopes, talus cones, and boulder fields.

69. Influence on Military Operations

a. Terrain exercises a dominant influence upon strategy and tactics. What aspects of the terrain are most important at any given time will depend upon the particular requirements of the command concerned. Logistic requirements, for example, may emphasize the importance of communication centers, road and rail nets, and waterways. The tactics of a large-scale campaign may be dictated chiefly by the barriers imposed by major rivers and lakes, mountains, forests, or swamps.

b. In the attack, the correct use of terrain increases fire effect and diminishes losses. Commanding elevations form the framework of the system of observation, which in turn directly determines the effectiveness of supporting weapons, the disposition and control of the attacking forces, the selection of objectives, and protective measures. Broken terrain, heavy woods, built-up areas, and abrupt changes in elevation hinder the offensive employment of armor but afford cover and concealment for infantry. Open, rolling terrain, although providing little cover and concealment for infantry, is suitable for rapid advances by armored formations. Soil trafficability, as influenced by the weather, may be a determining factor in the type of attack formation or avenue of approach that is employed.

c. The nature of the terrain is a major factor influencing the commander in his decision as to whether he will conduct a position defense or a mobile defense. When the terrain restricts the ability of an

attacking enemy to maneuver and provides natural lines of resistance, a position defense may be desirable. Terrain that facilitates maneuver by defending forces will favor a mobile type of defense. In selecting the key areas to be defended within a position, the commander depends largely upon a terrain study that considers and evaluates the terrain in all its military aspects. In addition, a thorough terrain study frequently will give valuable indications as to probable enemy assembly areas, field and air defense, artillery positions, observation posts, and avenues of approach.

d. Terrain has a decided influence on all retrograde movements. Good observation and fields of fire are desirable to permit engagement of the enemy at long ranges. Natural and artificial obstacles are exploited to strengthen defenses, protect exposed flanks, and impede the enemy advance. Concealment and cover are essential for assembly areas and routes of movement. Road nets are exploited to expedite the movement of friendly forces and to facilitate control, and are denied to the enemy for the same reasons. The effects of weather on the terrain influence observation, trafficability, control, and the performance of troops and equipment.

e. The maximum effects from nuclear weapons are obtained in flat, open terrain or gently rolling terrain because there are no irregularities to provide protection from the blast effect. Since thermal radiation travels in a straight line, any terrain feature which causes a shadow will shield personnel within the shadow from such radiation. Similarly, terrain features between the point of burst and the individual provide some protection from nuclear radiation.

Section II. LANDFORMS

70. Plains

a. *Definitions.* As a landform group, plains are generally flat to rolling areas with uplands or interstream areas less than 500 feet above adjacent valley bottoms. A *dissected* plain is one with a surface that is interrupted by erosional features, and an *undissected* plain is one with a smooth uninterrupted surface.

b. *General Characteristics.*

- (1) Plains are located at various altitudes. Some plains are several hundred feet above sea level while others, situated behind topographical barriers, such as mountain ranges, are at elevations below sea level. Plains differ in surface characteristics, some being rough and rolling while others are very flat.
- (2) Because of their low degree of local relief, plains generally have low angles of slope. In temperate climates, this characteristic makes them easy to traverse by transportation routes. Where there is monsoon weather or a tropical cli-

mate, however, more reliable routes may be provided by higher terrain.

- (3) The details of plains' relief include uplands and lowlands, ridges and valleys, and hills and hollows, all within local ranges of elevation of 500 feet or less.

c. Classification.

- (1) Plains are classified as—

- (a) *Flat*. Local relief of less than 50 feet.
- (b) *Undulating*. Local relief of 50 to 150 feet.
- (c) *Rolling*. Local relief of 150 to 300 feet.
- (d) *Roughly dissected*. Local relief of 300 to 500 feet.

- (2) According to slope, plains may be considered *smooth* when they have large areas with a slope of less than 2 percent, and *rough* when there are large areas with a slope of more than 2 percent or many small areas with steep slopes.

d. Types. Detailed information about the types of plains and their geological characteristics is contained in TM 5-545.

- (1) *Coastal plains* are generally low and featureless (figs. 22 and 23). Frequently they have shallow valleys formed by streams that originate inland. Swamps usually are numerous. *Cuestaform* coastal plains are characterized by long, low ridges alternating with lowlands in bands several miles wide and many miles long generally parallel to the coast.
- (2) *Delta plains* formed by sediments deposited at the mouths of streams and rivers, are usually low and marshy, with a local relief of less than 50 feet (fig. 24). The features of greatest relief are the natural *levees*, which are low, broad banks of alluvium on either side of the stream channels. For pro-



Figure 22. Coastal plain (Yellowknife, Northwest Territory, Canada).



Figure 23. Coastal plain formed by volcanic lava (Hawaii).

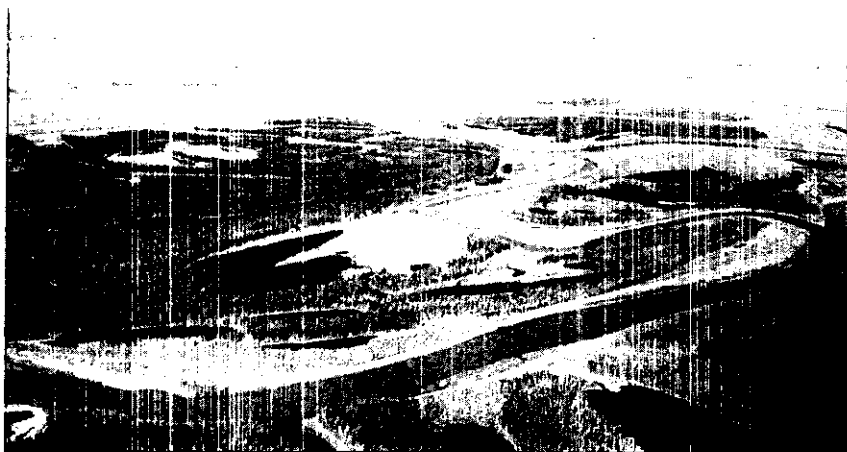


Figure 24. Delta plain (Mackenzie River, Canada).

tection against stream overflow, artificial levees may be built near the stream on top of the natural levees.

- (3) *Flood plains* or *alluvial plains*, are formed by weathered and eroded material deposited by streams upon the floors of their valleys. The flood plain usually is poorly drained, and may

contain marshes, swamps, lakes, and channels. Unless protected by levees, it may become partly or completely covered by water in times of flood. The surface is flat, the levees alternating with swamp areas. Meandering rivers and oxbow lakes are characteristic of this type plain (fig. 25). The silts and clays deposited on flood plains make productive soils, and this type plain is used extensively for agriculture.

- (4) *Piedmont plains* are alluvial plains formed by mountain streams with steep gradients that deposit a sediment, consisting largely of gravel and sand, at the point where the stream enters the lowlands. This type of plain is found in arid and semiarid regions with meager vegetation and tor-

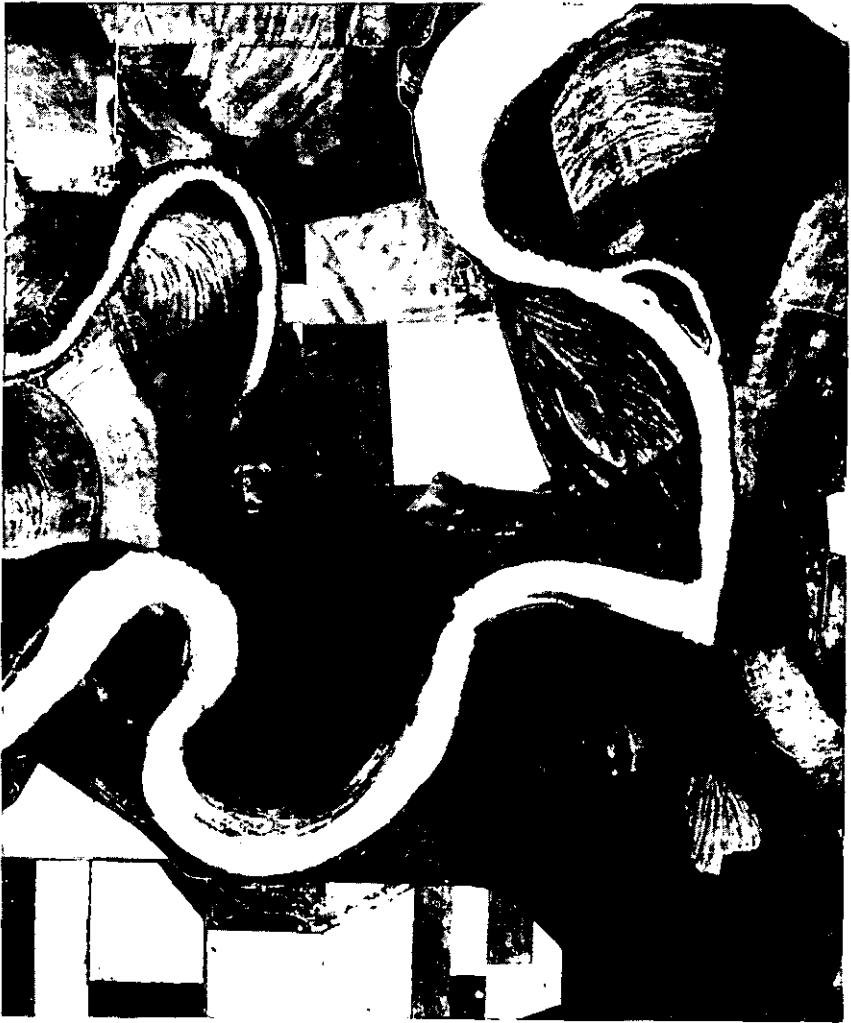


Figure 25. Meandering river, showing flood plain and oxbow lakes.

rential rains. While the plain may appear level, actually it slopes away from the mountain base. Many piedmont alluvial plains are covered only with shrubs or sparse grass. Those with fine soils are high in mineral plant foods and, if irrigation water is available, they are suitable for agriculture.

- (5) Glacial plains (fig. 26) are classified as either *ice scoured* or *drift plains*.

(a) *Ice-scoured plains* are level to gently rolling areas composed largely of bare rock. They are characterized by rounded rock hills, broad open valleys, and basins with comparatively low local relief. Over the valley floors there may be a thin covering of glacial debris which serves as an anchorage for shallow-rooted trees, chiefly conifers. There are numerous falls, rapids, and lakes. Some small shallow lakes become filled with the remains of marsh vegetation, such as sphagnum moss, creating bogs of the type called *muskeg* in Canada.

(b) *Drift plains* consist largely of boulders, gravel, sand, or clay in layers of varying thickness on top of other strata of rock and soil. The principal characteristic is a gently undulating surface which includes broad, low hills, or *swells*, and wide, shallow depressions, or *swales*. Commonly the local relief is less than 100 feet. In some localities there are hills of clayey till called *drumlins* (fig. 27) that occasionally reach heights of more than 100 feet and may be a mile long. Streams in this type of plain may be interrupted by swamps, lakes, falls, or rapids.



Figure 26. Glacial plain (Moose Jaw, Saskatchewan, Canada).

- (6) *Lacustrine plains* are formed by sediment settling on lake bottoms. They are level and often contain salty or alkaline lakes. Generally they are characterized by poor drainage and alkaline soils.
- (7) *Loess plains* are formed by windblown particles of silt, called *loess*, which have been deposited over large areas, forming a smooth, gently sloping surface. The ability of loess to stand in vertical walls results in steep escarpments along gullies, stream valleys, and artificial cuts.
- (8) *Karst plains* (fig. 28) are a type of erosional plain developed on limestone. They have a pinnacled or pitted surface formed by the solvent action of underground water. This type of plain has an undulating, rolling, or rough surface with numerous depressions. Between the depressions there are



Figure 27. Drumlin (New York).



Figure 28. Karst plain (Canada).

low, irregular ridges or hillocks. Numerous caverns are formed beneath the surface of a karst plain, and there are also large underground streams which may issue at the surface as springs of considerable volume.

71. Plateaus

a. Definition. A plateau is a plain that is elevated several hundred feet or more above adjacent lowlands. A plateau is commonly bordered by an escarpment or steep slope on at least one side. Hills and deep valleys may exist on the plateau surface.

b. Characteristics. Plateaus vary greatly in configuration, but all of them are characterized by broad uplands of considerable elevation above sea level. Some parts of the plateau surface are likely to be traversed by deeply cut and relatively narrow stream valleys. Depending upon the stage of the erosion cycle, the valleys that dissect the plateau may be widely spaced early in the cycle or very extensive late in the cycle (fig. 29). Most large plateaus are in regions with arid or semiarid climates.

c. Types. Plateaus may be classified in three major types—

- (1) *Intermountain* (fig. 30). Surrounded or nearly surrounded by mountains.

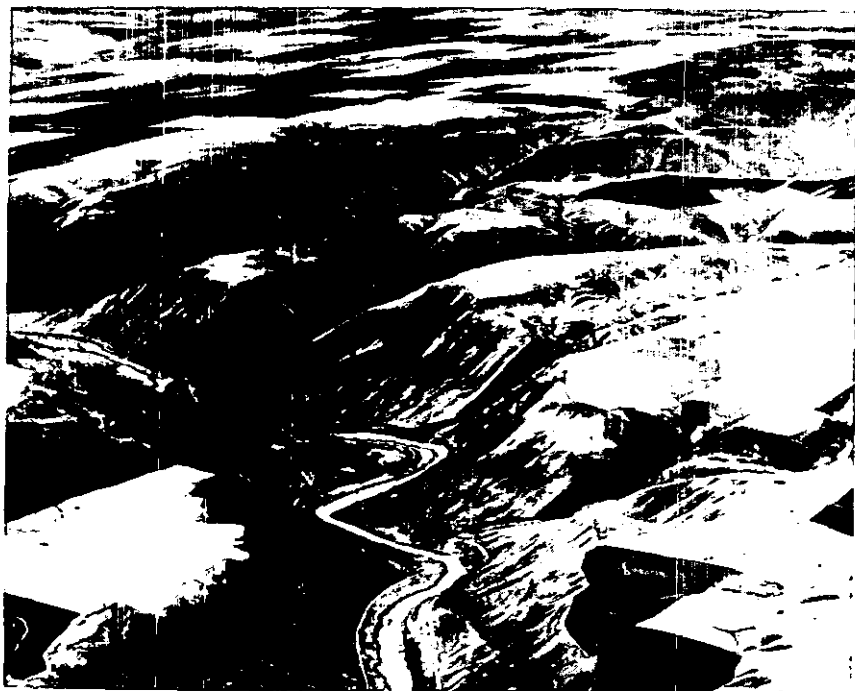


Figure 29. Plateau dissected by stream (Deschutes River, Oregon).



Figure 30. Intermountain plateau (Jackson Hole, Wyoming).

- (2) *Piedmont*. Lying between mountains and plains, or between mountains and the sea.
- (3) *Continental* (fig. 31). Rising abruptly from bordering lowlands or the sea on most or all margins; usually without conspicuous mountain rims.

d. Arid Climates. In arid climates, streams usually flow in canyons cut into the plateau. The typical canyon in an arid climate has a narrow bottom offering little space for a roadway. The stream is seldom navigable and follows a steep, boulder-stream course interrupted by rapids and falls. Sudden and extensive changes in stream level are common. Canyons usually are too deep to be crossed easily and too wide to be bridged economically. They rarely provide a transportation route and are a difficult obstacle to movement. Areas between the streams usually are flat or rolling uplands, some of vast extent. Areas of interior drainage called *bolsons* exist on some plateaus. The streams empty into these, resulting in level areas that may contain large salt lakes or salt marshes.

e. Humid Climates. Plateaus in humid climates tend to be more dissected by stream erosion than those in arid climates. Broad divides with rounded and irregular uplands are common.

f. Ice Plateaus. The vast sheets of ice that cover most of Greenland and Antarctica may be regarded as great plateaus. Greenland is an intermontane plateau, surrounded by a fringe of mountains. In most of Antarctica, the ice rises in a sheer wall, then slopes up rapidly to a fairly level interior with an average elevation of about 6,000 feet, the maximum elevation of 10,000 feet being found in regions inland from the Pacific coast. In general, the surfaces of an ice plateau are flat or have parallel ridges a few feet in height which result primarily from the wind and drifting snow.

- (1) *Marginal features of Greenland.* The highland or mountainous rim and the higher summer temperatures of Greenland produce marginal features which are different from those of Antarctica. The ice is held in by the highlands, melting some distance inland on the southern and western margins. Where ice does not discharge into the sea, it protrudes through gaps in the bordering highlands (fig. 32). Irregular icebergs form, drifting into the Atlantic Ocean during the spring months.
- (2) *Marginal features of Antarctica.* The marginal ice of Antarctica is thin and traversed by deep cracks. Except in a few localities where it is retained by the fringing mountains, the ice overruns the land margins, so that the exact position of the continental shoreline is not known. The edge of the ice is marked by sheer cliffs. From these giant icebergs split off along crevasses as a result of undercutting



Figure 31. Eroded continental plateau (Grand Canyon, Arizona).

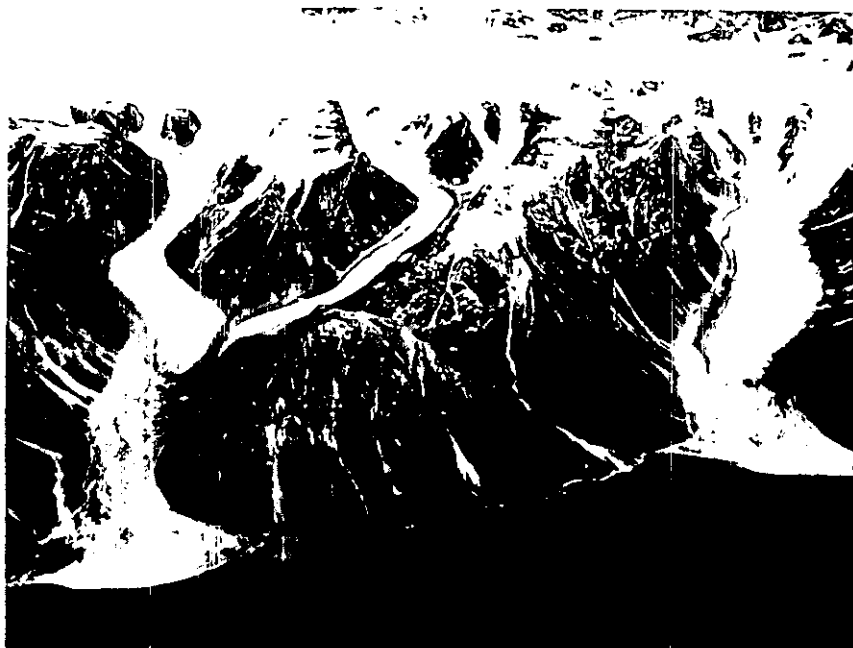


Figure 32. Tongues of icecap descending toward fiord (Greenland).

by waves and the buoyant effect of sea water. Some of these are tens of square miles in area. The icebergs disintegrate by melting and disperse as masses of floe and drift ice which fringe the continent for many miles.

72. Effects of Plains and Plateaus on Military Operations

a. General. While plains and plateaus are characterized by relatively low relief compared to hills and mountains, they present a wide variety of topographical conditions. Since each type of plain or plateau differs in its features and the effects it will have upon the military aspects of the terrain, one can only generalize about their influences on military operations.

b. Movement.

- (1) *Coastal plains.* In general, the topography of coastal plains offers no major obstacle to the cross-country movement of tracked vehicles, although there may be areas that are difficult or impracticable because of unfavorable soil conditions and dense vegetation in areas of medium to heavy rainfall. Movement along an indented shore usually is difficult because the terrain is separated into compartments by streams and estuaries. Cross-country movement inland may be limited to narrow areas bordered by water. In such terrain, attacks may require amphibious support. Coasts with beach ridges

hinder an advance inland because vehicles must cross poorly drained areas between relatively stable sand ridges. Terrain of this type impedes the adequate dispersal of troops and supplies.

- (2) *Delta plains.* On delta plains cross-country movement usually is hindered by marshy ground, shifting streams with loose sand and mud bottoms, and thick vegetation. Soils are better drained in the inner regions of the delta. Normally the natural levees of streams provide the highest, best-drained, and most trafficable parts of the delta. Movement on the low-lying grounds of delta plains is always threatened by the possibility that the enemy will destroy dikes or levees and flood the area.
- (3) *Alluvial plains.* The stream valleys in alluvial plains generally provide corridors through areas of greater relief. In dry weather, the cross-country movement conditions usually are excellent, except for such obstacles as streams and local areas of unfavorable soil or heavy vegetation. In wet weather or during floods, movement may be limited to small areas of higher, better-drained ground, such as levees. Alluvial terraces are above flood levels and may be well-drained, but they are commonly isolated by steep slopes.
- (4) *Glacial plains.* The topography of glacial plains usually presents no insurmountable obstacles to movement. Large boulders may be obstacles in some areas. In regions containing large areas of soft ground, lakes, or marshes, movement in the summer may be greatly hindered by mud.
- (5) *Lacustrine plains.* No topographic obstacles to movement are offered by the level surface of lacustrine plains. During wet weather, however, the fine soils may be slow-drying and become nontrafficable.
- (6) *Loess plains.* In dry weather, movement conditions on loess plains are good, except where escarpments and ravines are encountered. Ground conditions may become very poor in wet weather, making cross-country movement impracticable.
- (7) *Karst plains.* Movement on karst plains is limited chiefly by the sinkholes, which may have steep slopes and contain swamps and ponds. In wet weather the clayey residual soil overlying the limestone may limit movement in some areas.

c. Observation. The degree of observation available on coastal plains is normally good along the coastline, but inland the flat country and forest cover usually offer few observation points. Observation is limited on delta plains because the low, level ground generally is covered thickly by vegetation. On alluvial plains, observation from the valley bottoms usually is poor, but the bordering regions provide

commanding views into the valleys. Observation varies in glacial plains. Where vegetation does not interfere, it may be good on the more level portions of these plains. Vegetation also determines the amount of observation that may be secured in lacustrine, loess, and karst plains.

d. Concealment and Cover. Coastal plains provide few areas with sufficient concealment and cover for larger units. Except for the levees, there are also few topographic features on delta plains that will conceal or protect troop bodies of any size. Little concealment and cover are available on alluvial plains, except for that provided along terraced scarps, river banks, and levees. On glacial plains, cover is lacking in the more level parts, but there may be some limited concealment and cover provided by knobby and forested areas. The sinkholes of karst plains also provide a moderate degree of concealment and cover.

e. Construction.

- (1) *Coastal plains.* While generally there is no hard rock on coastal plains, sand and gravel are abundant on beaches and along streams. The ground of coastal plains is excavated easily, but the depth of excavation usually is limited by the high water table. Long and straight road alignments normally can be obtained. There are many suitable sites for airfields, particularly along the marine terraces.
- (2) *Delta plains.* Abundant sand and fine binder material may be obtained on delta plains, but gravel is scarce. There are no exposed hard-rock formations or bedrock. Generally the location of airfields and roads must be confined to the levees. Structural foundations not built upon levees are unreliable, and may settle due to the low, poorly-drained ground. There is also the threat of periodic flooding. Drainage always is a serious problem. The levees prevent the return of surface water to the river, and the high water table limits underground return. Accordingly, drainage and pumping systems may be required.
- (3) *Alluvial plains.* Rock is scarce in flood plains except where it may crop out along the scarps of terraces. Sand, gravel, and binder material are abundant along stream channels and the terrace scarps. Terraces also may provide suitable sites for bunkers and underground installations. Excavations in flood plains are limited by the high water table. Flood plains and terraces if well drained are suitable for the construction of roads and airfields, even though the foundations may not be entirely satisfactory.

- (4) *Glacial plains.* Sand and gravel are widely distributed on glacial plains, and rock usually is abundant. On till plains, boulders may provide building stone, but there is bedrock only in a few locations, such as in deep valleys where the overlying till has been cut through. Wet ground and weak soils may create foundation problems where the drainage is not good. Generally the ground is easily excavated.
- (5) *Lacustrine plains.* Except at the marginal slopes, where sand, gravel, and rock may be obtainable, lacustrine plains usually can provide only clay and fine sand for construction purposes. The fine-grained soil makes a poor foundation for structures, particularly in humid climates. Lacustrine plains provide level sites for airfields with few natural obstructions and allow unrestricted road alignments.
- (6) *Loess plains.* Loess plains are a poor source of gravel or rock, except where there are underlying deposits. Foundations require stabilization and in cold climates the loess may heave. In dry climates, thick loess deposits are easily excavated and are well suited for underground installations. Many good airfield sites and road alignments usually are available.
- (7) *Karst plains.* Large quantities of limestone for building stone and crushed rock may be obtained on karst plains. Sand and gravel usually are lacking. Excavation often is difficult because of the irregular rock surface, with deep clay-filled pits, and the high pinnacles of rock that lie beneath the residual soil. Grading usually requires the excavation of rock. There is always a possibility of foundation subsidence.

73. Information Requirements Plains and Plateaus

a. Plains.

- (1) Extent of area covered by plain.
- (2) Surface.
 - (a) Elevation.
 - (b) General slopes.
 - (c) Nature of surface (flat, undulating, rolling, roughly dissected).
- (3) Major interruptions.
 - (a) Hills or mountains rising above plain.
 - (b) River valleys cut into plain.
- (4) Minor interruptions.
 - (a) Gullies.
 - (b) Sinks.
 - (c) Natural levees.

b. Plateaus.

- (1) Area covered plateau.
- (2) Surface.
 - (a) Elevation.
 - (b) General slope.
 - (c) Nature of surface.
 - (d) Minor relief features
- (3) Major interruptions.
 - (a) Hills or mountains rising above plateau surface.
 - (b) Canyons or valleys cut into plateau surface.
- (4) Margins.
 - (a) Mountains rising above plateau.
 - (b) Cliffs descending abruptly from plateau.

74. Mountains

a. Definition. As a landform group, mountains are rugged areas with crests that are, in general, more than 2,000 feet above adjacent lowlands. They are commonly distinguished from other major relief features by their predominance of slopes and their overall massiveness.

b. Classification.

- (1) In terms of local relief, mountains may be classified as *low* when they have a local relief of 3,000 feet or less, and *high* when their height exceeds that figure.
- (2) According to their size and arrangement, mountain features may be classified as—
 - (a) *Peaks.* A peak is a high mass, more or less conical in outline, that rises above its surroundings. Ordinarily a peak is a feature of minor order upon a range, but in some instances, as in the case of an isolated volcanic cone, one may stand alone and comprise the entire mountain mass.
 - (b) *Ranges.* A range is an arrangement, usually linear, of many peaks, ridges, and their valleys. The term ordinarily applies to mountains that have a general unity of form, structure, and geologic age.
 - (c) *Mountain chain.* A mountain chain consists of several associated ranges, usually more or less parallel, having unity of position, form, or structure, but separated by trenches or basins.
 - (d) *Cordillera.* A cordillera is a large regional grouping of mountain chains.

c. General Characteristics.

- (1) Mountains are distinguished from hills by their greater relief, more rugged contours, and more complicated surface patterns. The geological formation and structure of mountains are discussed in TM 5-545

- (2) The steepness of mountains usually is less than it seems to an observer. The average slope of large mountains seldom is more than 20 or 25 percent from the horizontal, and only a few have slopes of more than 35 percent near the summit. Even walls that seem vertical seldom have slopes of more than 70 percent.

d. *Major Relief Features.*

- (1) *Valleys.* Except where they have reached grade level and meander in flat alluvial valleys, mountain streams have high gradients and flows of high velocity. The rapid downward cutting action of the stream may uncover bedrock of unequal hardness, so that falls and rapids develop. Some streams, in cutting through bedrock of unequal resistance, erode valleys which are broad at their headwaters, then narrow to gorges, and subsequently open out again downstream. Valleys formed by glacial action have wide rounded bottoms and steep sides. They have U-shaped profiles, in contrast to the V-shaped profile of a stream eroded valley (fig. 33). The walls are steep and rugged. Most glaciated valleys have one or more basins in which impounded drainage creates lakes, ponds, or marshes.
- (2) *Divides.* Between the mountain valleys there are uplands formed by remnants of the original elevation. Rainfall on these uplands separates according to the surface slopes and descends by numerous rivulets into adjacent valleys, modeling the uplands as it flows. The uplands are called *divides*. When they separate the drainage destined for opposite sides of a continent they are termed continental *divides*.
- (3) *Foothills and spurs.* The lowest and least massive features of mountain uplands are the foothills and spurs that fringe the principal highlands. *Foothills* are hills located at the base of higher mountains or hills. A *spur* is a ridge projecting laterally from the main crest of a hill or mountain.
- (4) *Peaks.* The term *peak* is applied generally to the highest point or most prominent summit area of a hill or mountain. A hill or mountain with a conspicuous summit may also be called a peak.
- (5) *Passes.* The erosion of streams or glaciers creates saddle shaped notches, or *passes*, in a mountain barrier. The term *pass* is applied to any type of natural passageway through high, difficult terrain.

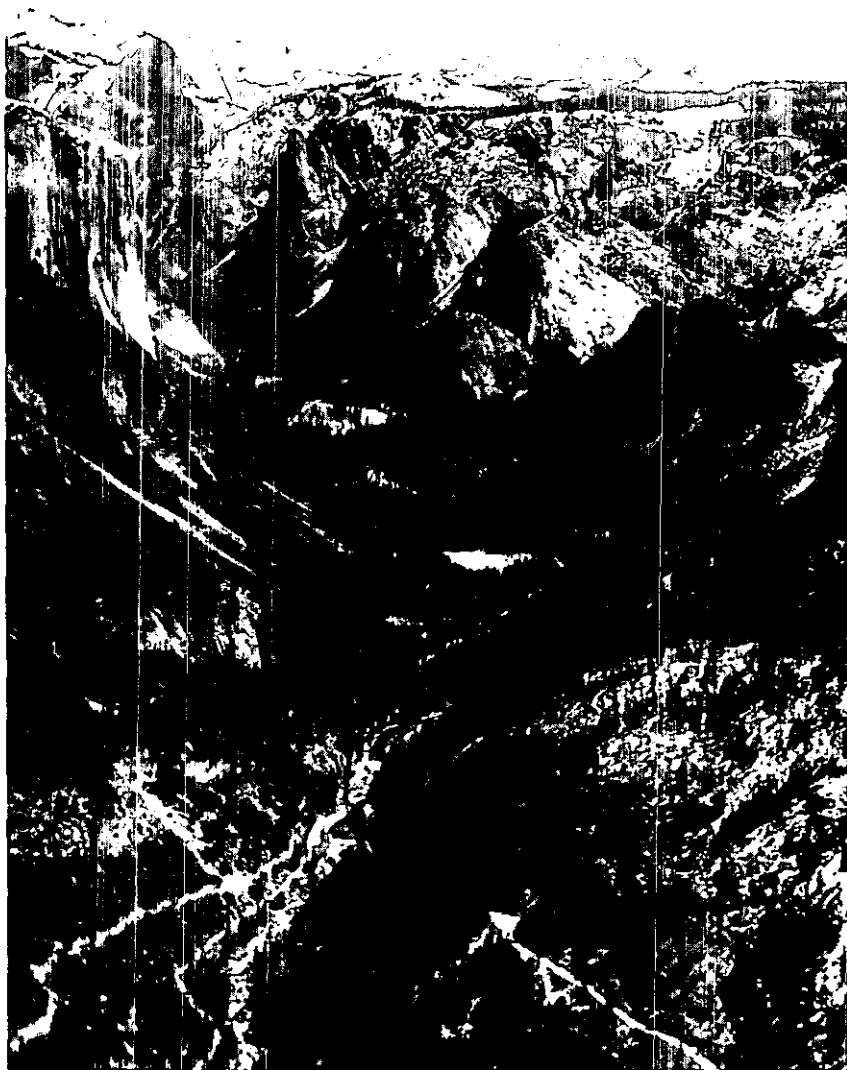


Figure 33. U-shaped valley (Yosemite Valley, California).

75. Hills

a. Definition. As a broad landform group, hills are rough areas with crests generally from 500 to 2,000 feet above adjacent lowlands. They usually contain a predominance of moderate slopes.

b. Classification. Hills may be classified as *low* when they have a local relief of from 500 to 1,000 feet, and *high*, when the local relief is from 1,000 to 2,000 feet.

c. General Characteristics. Some very rough hills may appear mountainous in relation to adjacent plains, and locally may be called mountains, but they are not properly of a size or nature to merit the term. Mature hill lands may be almost entirely a succession of hills, valleys, and narrow ridges, with level land occupying less than five percent of the total area. Hill regions in an early stage of erosion may include some fairly level, plateaulike uplands separated by steep-sided valleys. Those in a more advanced erosional stage may have broad open valleys and reduced slopes that are suitable for agriculture. Because some of the slopes in hill regions are steep and untillable, they have retained their forest cover and have streams with steep gradients that are capable of developing waterpower.

76. Effects of Hills and Mountains on Military Operations

a. Movement.

- (1) Hills and mountains parallel to the axis of advance offer flank protection to an advancing force, but limit lateral movement. When they are perpendicular to the axis, they are an obstacle to the attacker and aid to the defender.
- (2) Major obstacles to cross-country movement in hills and mountains include steep, high ridges and ranges; high valley routes and escarpments; precipitous sloping cliffs, terrace faces, and valley ends. Minor obstacles include stream embankments, valley terraces and benches, spurs, talus and debris-choked valleys, and boulder-covered slopes and uplands.
- (3) Roads usually are inadequate in mountainous areas, and must be improved for military use. The existing roads are generally narrow, making two-way traffic difficult, and have steep grades and inferior surfaces. Sharp turns may prevent the use of trailers. Roads usually are located in valleys or along defiles, and the adjacent high ground must be secured to insure control of the roads. Mountain roads are vulnerable to slides and avalanches and may be blocked by snow.
- (4) Roads on the crests of ridges are undesirable because they may be exposed to enemy observation. Roads at the bottom of defiles also may be unsuitable because of the

possibility of torrential floods and the presence of large boulder-strewn areas. In mountains and hill regions, the best sites for military roads normally are found on the sides of slopes.

b. Observation. In hilly and mountainous areas, observation may be restricted by the high relief. In most cases, commanding heights provide only partial observation of adjacent valleys and slopes. Foothills and spurs extending into a valley obscure observation along the valley.

c. Concealment and Cover. The rugged topography of mountains offers abundant concealment and cover, although movement across slopes or crests above the timberline will be exposed to observation. Sounds carry plainly from valley bottoms to hill tops. In the valleys, sounds are muffled by ground forms, foliage, and flowing streams.

d. Key Terrain Features. In both attack and defense, the key terrain features may include the heights which dominate valleys, the routes of communications, passes and valleys which permit cross-country movement through the mountains, and aircraft landing areas. Dominating heights which may be used by the enemy for observation of avenues of approach must be controlled.

e. Effectiveness of Weapons.

- (1) Mountains and hills place some restrictions upon the employment of supporting weapons. Armor loses much of its mobility because it cannot move across country. Occasionally tanks can be used in small numbers against limited objectives, but their action often is confined to providing direct fire support. Artillery is effective, but the limited visibility in mountainous terrain restricts the observation and adjustment of fire. Terrain features may also reduce the effectiveness of air defense artillery by making radar siting difficult and reducing the target acquisition range of the system. Survey and fire control are hampered, and more time is required for artillery to displace. There is difficulty in finding gun positions that do not have too much defilade.
- (2) The heavier crew-served weapons of the infantry and their ammunition are difficult to carry over the rugged terrain. Mortars and recoilless rifles are effective and are favored for operations in mountains and hill regions.
- (3) Deep valleys and ravines afford a degree of protection from the blast effect of nuclear weapons when the axis of the valley or ravine points well away from ground zero. When it does not, there is little or no shielding effect, and blast damage may be increased because the blast is canalized. Deep valleys and ravines afford substantial protection from

thermal and nuclear radiation to troops, materiel, and buildings located within the shaded portions. In terrain characterized by deep valleys and ravines, however, blast effects of nuclear weapons may cause serious avalanches and rock slides.

- (4) Concentrations of toxic chemical agent aerosols are extremely hard to achieve on marked downward slopes. Toxic chemical agents and biological agent clouds tend to flow over rolling terrain and down valleys, to remain in hollows and on low ground and in depressions, but to go around obstacles. Local winds, coming down valleys at night or up valleys in the daytime, may deflect the clouds or reverse the forecast flow; likewise they may produce favorable conditions for cloud travel.

f. Communications. Hills and mountains contain dead spaces that often limit the range and effectiveness of radios, although these restrictions usually can be overcome by the use of relay sets. Messengers are slow and often get lost. Visual signals are not always dependable and can often be seen by the enemy. Wire-laying is difficult.

g. Air Support. The hazards of flying in mountainous regions place some limitations upon the use of low-flying combat aviation. Targets are difficult to locate and in many cases close air-support strikes must be controlled by indirect means, since the functions of tactical air-control parties are hindered by the terrain and weather.

h. Tactics.

- (1) Combat in mountains and hilly areas usually consists of a series of independent actions to seize and hold commanding terrain, strike communication lines, and protect friendly routes of supply and evacuation. Infantry plays the dominant role, since it is not roadbound and can close with the enemy under almost any condition of terrain.
- (2) Commanding positions in mountain terrain are often rocky ridges or eminences with little or no soil. If the importance of the position justifies the time and effort required, trenches, emplacements, and galleries can be cut into the solid rock. Parapets and breastworks of cobbles and boulders are effective against small arms, but they are vulnerable to artillery fire. Log breastworks and protective shelters may be built if timber stands are conveniently located.
- (3) Mines and obstacles find their most important use in obstructing movement on roads and trails and through defiles. Roadblocks are effective because of the difficulty of bypassing them.
- (4) Mountainous terrain favors the defender. It provides strong obstacles which he can use with a minimum of troops to

deny the attacker the use of existing routes of communication, forces deployment of major enemy units and the expenditure of large amounts of mortar and artillery ammunition, and inflicts the maximum punishment from protected positions.

i. Construction.

- (1) Many types of hard rock suitable for construction purposes are readily obtained in hills and mountains. Sand is scarce, but gravel may be secured in the lower stretches of streams where they approach the foot of the mountains or flow through hills.
- (2) There are few suitable locations for airplane runways in hills and mountains. The problems encountered include the difficulty of excavation in rock, obstructed and limited approaches, poor accessibility, and turbulent air currents.
- (3) Highways, railways, and tunnels are very vulnerable in hilly and mountainous areas. Geologic data may be useful in indicating rock conditions favorable to initiating rock slides by bombing or artillery fire and thus blocking enemy lines of communication. Information about the geological formations will also assist in selecting sites for gun emplacements and other fortifications, estimating the probable effect of fire on rock fragmentation, and determining the possible ricochet effects of projectiles.
- (4) The soil that exists in hilly and mountainous regions usually is thin or stony, with underlying bedrock, so that it is difficult to construct temporary field fortifications. Geologic study will assist in selecting areas where excavations may be made most readily as well as the explosives and equipment that will be required.

77. Information Requirements, Hills and Mountains

a. Extent and Type of Mountains or Hills.

b. Ridge Crests.

- (1) Location and orientation.
- (2) Elevations (typical, highest, lowest).
- (3) Height above adjacent valley flats (average, highest, lowest).
- (4) Pattern (long straight, parallel ridges; branchlike and crooked ridges; clusters of knobs and peaks).
- (5) Skyline (flat-topped and broad, or knifelike).

c. Slopes.

- (1) *Shape (convex, concave).*
- (2) Angle, in percent or degrees (near crest, middle, near base).
- (3) Minor relief features (rough lava, boulder fields and gullies).

d. Valley Flats.

- (1) Location.
- (2) Width (of main and tributary valleys; average, widest, narrowest for both categories).
- (3) Pattern (long, straight, and parallel valleys or branchlike and crooked valleys).
- (4) Transverse profile (degree of slope near center and margin of valley).
- (5) Longitudinal profile (degree of slope near mouth and head of valley).
- (6) Terraces (benchlands) along borders of valley flats (number of terrace steps, width, continuity, elevation of steps one above another, slope between terrace levels).
- (7) Stream channels within valley (straight or meandering, bordered by bluffs, gentle downslopes, or natural levees).

e. Intermontane Basins.

- (1) Location.
- (2) Width (average, widest, narrowest).
- (3) Shape (round, oval, long and narrow, irregular).
- (4) Flat bottom lands (extent and location).
- (5) Terraces (benchlands) about borders of flat bottom lands (number of terrace steps, width, continuity, elevation of steps above one another, slope between terrace levels).

f. Passes.

- (1) Location.
- (2) Elevations (average, lowest, highest).
- (3) Number of passes (distance between passes).
- (4) Gradients (near head of pass, downslope).
- (5) When closed by ice and snow.
- (6) Character of defile formed by pass and approaches (width, length, character of slopes).
- (7) Routes over each pass.

Section III. DRAINAGE

78. General

a. The water features of an area comprise its drainage. They include streams and canals; drainage and irrigation ditches; lakes, marshes, and swamps; artificial bodies of standing water such as reservoirs and ponds, as well as such subsurface outlets as springs and wells. The character of these drainage features is determined by precipitation, relief, surface runoff and ground-water flow, and various manmade improvements.

b. Vegetation has a major influence upon drainage. Dense grass and tree growth on slopes tend to slow up and absorb a considerable

amount of the runoff, while slopes with few trees and sparse vegetation permit rapid runoff and the formation of channels by erosion.

c. A *catchment basin* or *catchment area* is the total area drained by a stream or system of streams. All water features within this area are related and are considered as a whole. The limits of the drainage basin are marked by the topographic divide which separates it from neighboring drainage systems. The amount of water reaching the stream, reservoir, or lake depends upon the size of the area, the amount of precipitation, and evaporation and transpiration. The rate of evaporation depends upon the temperature, vapor pressure, wind, and solar radiation.

d. Drainage patterns (fig. 34) reflect the subsurface structure. They are of three major types—*dendritic*, *trellis*, and *radial*.

- (1) A *dendritic* drainage pattern is a treelike arrangement of streams found most frequently in an area underlain by homogeneous rock.
- (2) The *trellis* pattern results from the influence of tilted alternating strata of weak and resistant rocks. The resistant strata separate each stream, producing the overall trellis effect.
- (3) The *radial* pattern has streams that radiate from a central dome that lies within a relatively flat area.

79. Rivers and Streams

a. *Types*. Rivers and streams are bodies of flowing water that may be classified as *perennial*, *intermittent*, or *ephemeral*.

- (1) A *perennial* stream flows throughout the year. The regular flow may result from a spring lake or a glacier at the head which furnishes a constant supply of water, from direct precipitation of fairly constant quality, or because the beds are deep enough to be permanently below the fluctuating upper level of the ground water or *water table*.
- (2) An *intermittent* stream originates in a source of water that fails periodically. This type of stream is particularly common in semiarid regions with seasonal rain or snowfall. Some streams are intermittent because they depend for supply upon the water table, and do not have beds deep enough to be independent of fluctuations in the table.
- (3) An *ephemeral* stream is temporary, depending upon surface water for supply.

b. *Bottoms*. Rivers and streams deepen their beds by erosion of the underlying rock until the beds are cut down to sea level. Differences in the load carried by the water at different points, in velocity caused by changes in grade, and in the degree of hardness of the rock make the beds uneven, producing gorges, cataracts, rapids, and potholes.

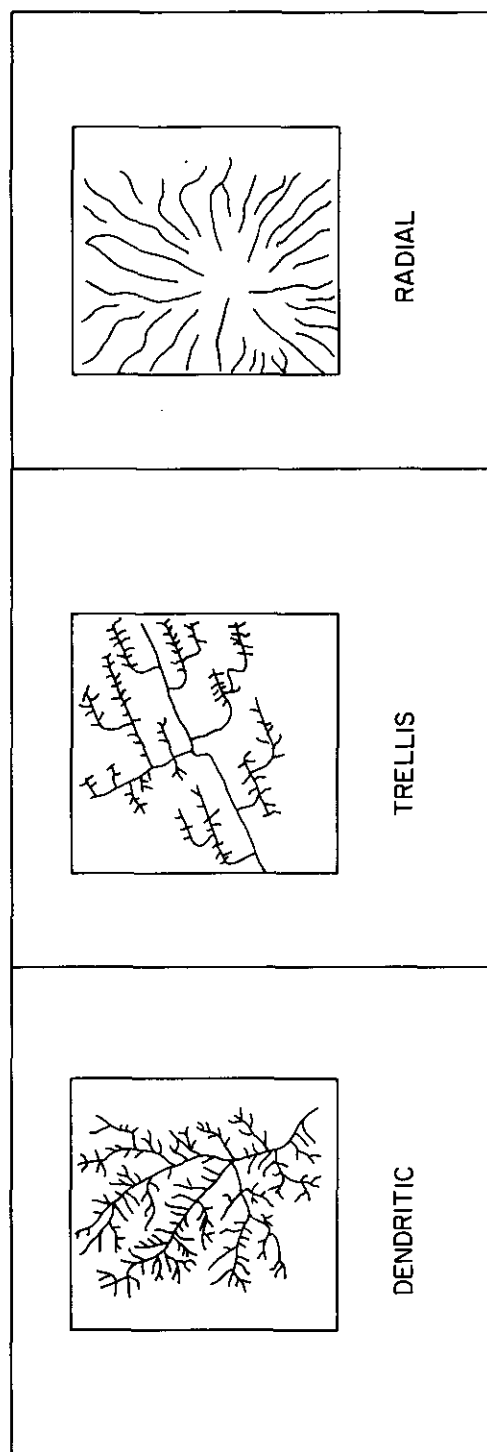


Figure 34. Drainage patterns.

Where streams have a high velocity and flow over loose materials, the bottoms commonly are narrow. In slow-moving water, fine material such as silt and clay is deposited, and the bottoms will be muddy. Sea level is the level of the oceans, but local temporary levels may be represented by lakes and inland seas above or below sea level.

a. Banks. After sea level is reached, sidewise cutting begins and the river widens its bed or develops a curving course. As a rule, these curves will have steep banks on the outside and gentle, low banks on the inside. The conformation will vary with the composition of the bank, the velocity of the stream, and the kind of materials transported by the stream. Compact soils form steeper banks than do loose soils. Swift streams in rough relief commonly cut deep channels with low banks.

d. Flooding. Some streams flood annually, while others do so only at infrequent intervals. Floods may be caused by rapidly melting snow, by excessive precipitation and runoff, by ice jams, or by any combination of these conditions. When a river is in flood, the velocity of water is greater than normal, with the fastest current in the main channel.

e. Desert Drainage.

- (1) Arid climates are characterized by long dry periods of infrequent precipitation. Desert streams for this reason are irregular in volume and duration of flow. Large areas of many deserts do not have streams flowing out of their immediate vicinity because the drainage net is centralized in interior basins. There may be separate basins at different elevations in each desert. Many large streams flow into desert lakes that have no outlet, or disappear through evaporation and seepage into porous surface material. Some streams encountered in deserts originate in humid regions, flow across the arid land, and then continue their course in another adjoining humid area.
- (2) When precipitation occurs in desert areas, it is likely to be in cloudbursts that generate a tremendous runoff as the water rushes down every available channel. Sheltered dry washes or *wadis* may become extremely dangerous locations for bivouacs, gun positions, and installations during these brief but violent floods.

80. Lakes

A lake is an inland body of standing water. Some lakes are formed by glacial action creating a depression which subsequently fills with water, the damming of a river by ice or a moraine, or by water filling a natural depression as a glacier recedes. A stream may be formed into a lake because of interference with its natural course

by a lava flow, dam, or avalanche. Coastal lagoons frequently are formed by the deposition of silt or sand at the mouth of a river. The crater of an extinct volcano often collects water and becomes a lake basin. Salt lakes occur when a lake is so poorly drained that the minerals in the water remain while the water evaporates. In limestone country, lakes caused by the filling of depressions of dissolved rocks are common.

81. Marshes and Swamps

a. Definitions.

- (1) A *swamp* (fig. 35) is an area of saturated ground dominated by trees and shrubs.
- (2) A *marsh* (fig. 36) is an area of saturated ground dominated by grasslike aquatic plants.
- (3) A *bog* is an area of soft, wet, spongy ground consisting of peat which supports mosses, low shrubs, and in some cases, poorly developed trees.

b. *Formation.* Swamps, marshes, and bogs are formed by the overflow of rivers, flooding by tides, a lack of balance between rainfall and runoff or seepage, impervious subsoil in level areas, or the spread of vegetation in lakes, particularly in oxbow lakes. They may be numer-



Figure 35. Swamp (Okefenokee Refuge, Georgia).

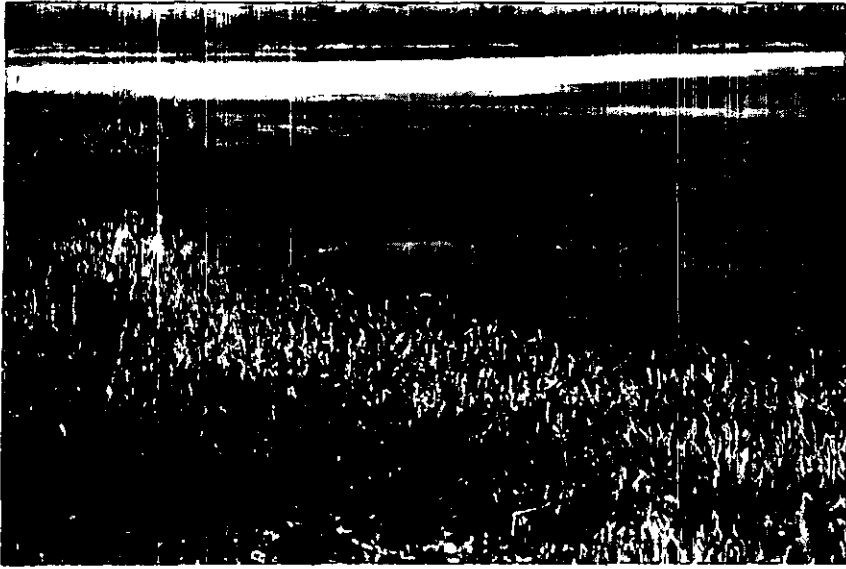


Figure 36. Marsh (Fozholm, North Dakota).

ous on delta and flood plains, where surface water is not readily drained. Extensive marshes and swamps are encountered on the plains of humid areas. In glaciated regions, marshes, bogs, and swamps are common.

82. Glaciers

a. A valley glacier (fig. 37) is a body of ice resulting from accumulations of snow in the valley heads of high mountains. The ice is formed from the compaction and recrystallization of snow and other forms of precipitation. As the ice mass expands it moves forward slowly, conforming to the shape of the valley in which it lies. The rate of motion is governed chiefly by the thickness of the ice, the steepness of the valley gradient, and the temperature of the ice.

b. Ultimately the advancing end of the glacier reaches lower elevations where higher temperatures prevail, and the ice wastes away by melting and evaporation. As long as the average forward movement of the ice is greater than the amount of waste, the front of the glacier will continue to move forward. The ice front remains stationary when the rates of advance and wasting are equal. If the rate of wasting is increased by several years of warm weather, the ice front will recede up the valley.

c. A continental glacier, such as those covering most of Greenland and Antarctica, begins with the accumulation of snow fields, not necessarily at high altitudes. After attaining considerable depth and area, the snow is transformed into ice, and the mass spreads outward under its own weight.



Figure 37. Valley glacier. (Alaskan coast. Kame terrace and outwash plain in right foreground.)

d. A glacier carries a load of rocks and earth, partly on the surface or frozen into the mass, but principally in its bottom. When the bottom becomes overloaded, the material is dropped upon the ice-scoured bedrock that lies beneath the advancing ice. The remaining load is deposited when the glacier wastes away, forming an area termed a *ground moraine* or *till sheet* composed of an earthy material called *till* or *boulder clay*. Great ridges of drift accumulate at the ends of glaciers. These are known as *terminal moraines*.

e. The streams of water that result from the melting of glacier ice carry large amounts of earth which are deposited near the margins of the glacier. These deposits are known as a *valley train* when they are arranged in the form of a flood plain, or an *outwash plain* when they spread in a broader, fanlike deposit at the glacier edges.

83. Ground Water

a. *Hydrologic Cycle* (fig. 38).

- (1) Water evaporated from the ocean is condensed into clouds, from which it falls to the earth as rain, snow, sleet, or hail. Part of this water runs off into lakes and streams, or is retained by the soil, passing into underlying rock formations. Moving through openings in the rocks, the water issues at the surface as springs, streams, and lakes.
- (2) Ultimately all the water that is precipitated returns to the atmosphere by evaporation from water surface or from the foliage of vegetation. Some also is released from foliage

by *transpiration* after extraction from the soil by growing plants. Transpiration is the process by which a plant transmits water through its tissues, discharging water vapor from its foliage.

- (3) Although this hydrologic cycle is irregular and may extend over a period of years, no water is lost permanently from circulation. The cycle may be bypassed or interrupted in stage. Rain falling upon a heavily forested area, for example, may return directly to the atmosphere by evaporation without going through other stages of the normal natural process.

b. *Water Table.*

- (1) When water fills the pores and crevices of the underlying rock, a *zone of saturation* results. This water is known as *ground water* and the top of the saturated zone is termed the *ground-water table*, or simply, the *water table* (fig. 39). The depth of the water table beneath the surface varies according to surface topography, structure of the rock formations, amount of rainfall, and nature of the pore spaces in the soil or rock.
- (2) Water stored below the water table is the source of supply for springs and wells. If the water table intersects the land surface, as it may on the sides of valleys, the water will flow or seep out as gravity springs or seeps.

c. *Springs and Seeps.*

- (1) Subsurface water issuing at the surface as a *spring* has a distinct current, flowing continuously or intermittently from a localized area. Water issuing as a *seep* emerges slowly over a large area, without a noticeable current. Springs and seeps are of two principal kinds: *gravity* and *artesian*.
- (2) *Gravity* springs and seeps are those in which the subsurface water flows by gravity from a higher point of intake to a lower point of issue. This may occur where the water table comes near or intersects the surface of the ground, usually around the margins of depressions, along the slopes of valleys, and at the foot of alluvial fans. Another type occurs along an exposed contact between the overlying pervious stratum and an underlying impervious stratum. They may appear at almost any elevation along a slope.
- (3) *Artesian* springs occur where confined subsurface water acting under the influence of pressure from a higher water level is forced to the surface of the ground. Fissures in the rock, fault zones, and, in some cases, solution channels may serve as avenues along which water can move to the surface.

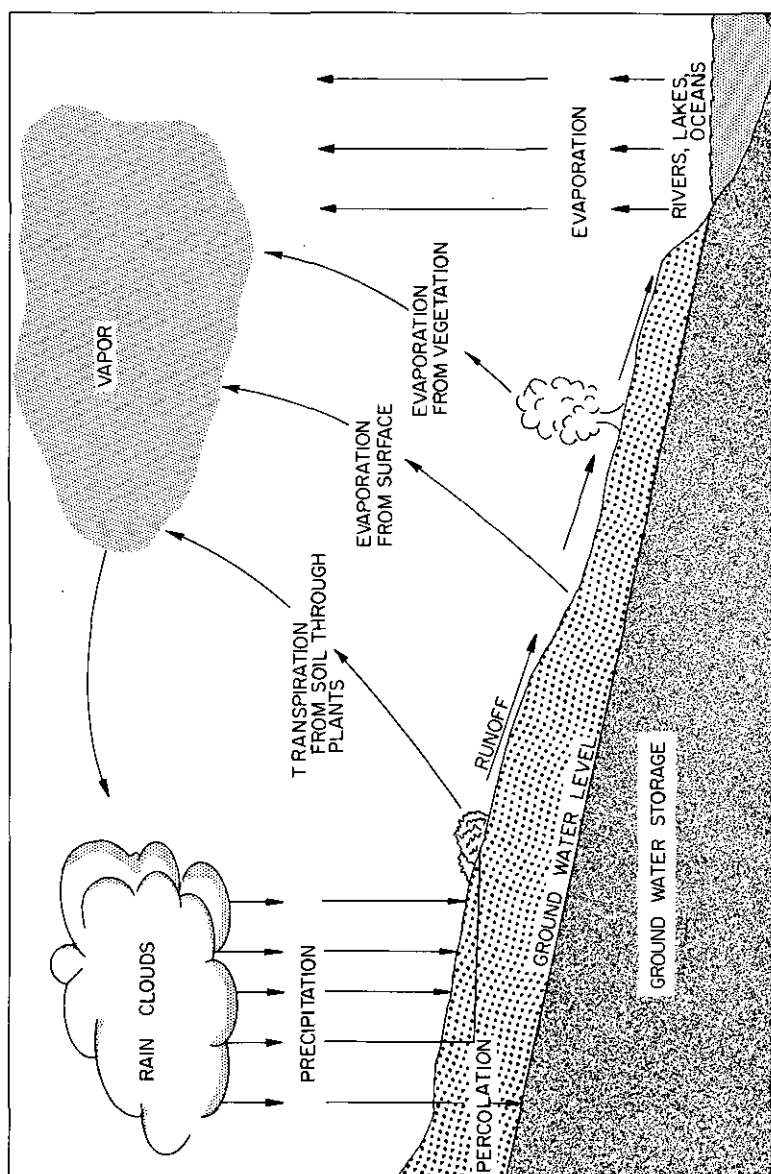


Figure 38. The hydrologic cycle.

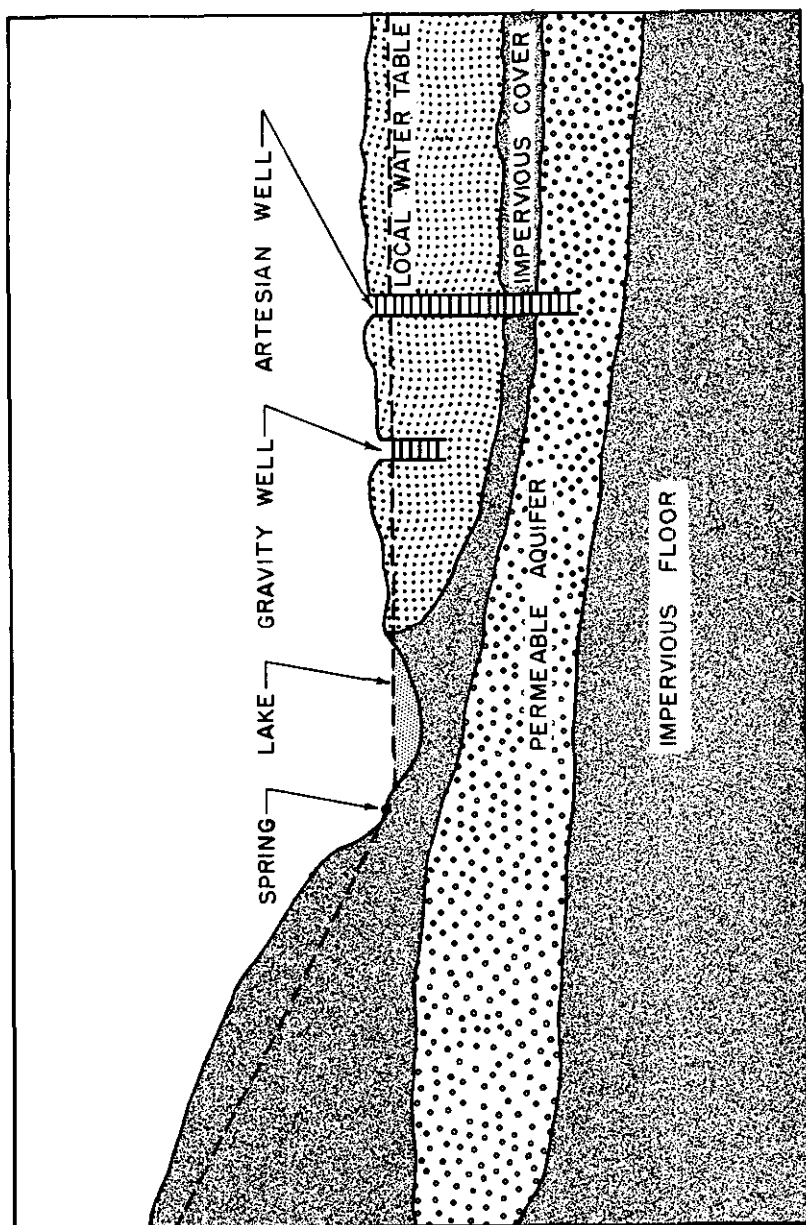


Figure 39. Water sources.

Artesian wells are those which flow freely without pumping, the water being raised to the ground surface by pressure upon the lower areas of the water-bearing formation.

d. Circulation.

- (1) Ground water is not static but moves slowly through openings in the rock and soil toward points of discharge. The rate of movement is controlled by gravity or hydrostatic pressure (the pressure exerted by water at a higher level) and by the capacity of the rock or soil to transmit water, termed its *permeability*.
- (2) Climate governs the amount of water that will be contributed to the surface. The amount that will be absorbed depends upon the amount of pore space, or the *porosity* of the ground.

84. Effects on Military Operations

a. Rivers and Streams.

- (1) Wide, deep rivers with valleys that offer concealment may provide good defensive areas. The employment of a river as a forward edge of battle area (FEBA), however, may also result in a frontage too wide for effective defense because of the meandering of the stream. There are likely to be many covered areas that interfere with observation and fields of fire. Often the terrain is marshy and intersected by ditches or tributaries which interfere with lateral communications and the movement of reserves.
- (2) In the attack of a river line, the initial objectives are key terrain features which permit the enemy to bring effective small-arms fire on the crossing area. Next in priority are features that allow the enemy to deliver observed artillery fire, and, finally, those areas on the enemy side of the river that are required to accommodate the troops, equipment, and installations necessary to prevent the enemy from delivering effective sustained artillery fire. A river or stream may be a temporary obstacle to cross-country movement, but it slows down advancing forces only until the necessary bridges can be erected, assault boats can be brought to the side, or a crossing by helicopter is effected. The effectiveness of a river as an obstacle increases with its width, depth, and velocity. Rivers more than 500 feet in width are major obstacles. River crossing operations are discussed in FM 31-60.
- (3) Rivers in flood are serious obstacles. Floods may cause traffic interruptions that extend for a considerable period, particularly by damaging temporary and expedient bridges. If no preparations have been made, a flood may immobilize a theater of operations. An adequate system of stream-gaging

stations and flood-warning agencies must be established for all key rivers in the theater.

- (4) Streams in mountainous areas are characterized by a high velocity with considerable variation in their flow. While they may be effective obstacles during flood periods, they usually are so low in dry seasons that their beds may offer routes of approach rather than obstacles to movement.

b. Lakes.

- (1) Usually lakes are obstacles to movement. Few lakes are narrow enough to be bridged, and they must be bypassed or crossed in amphibious vehicles or boats. Where lakes exist in chains or large groups, as in glaciated areas, they become major obstacles (fig. 40). The narrow land corridors separating the lakes canalize troop movements and limit maneuver, rendering troops highly vulnerable to attack both by regular enemy forces and guerrillas.
- (2) A series of interconnected lakes may provide an extensive communication system. Such a system may also include navigable rivers and canals, as in Finland.
- (3) An ice cover that is 3 feet or more in thickness will support heavy loads. Roads across frozen lakes may be prepared by clearing away the snow.

c. Marshes and Swamps.

- (1) Normally movement through a swamp or marsh is limited to causeways. These are key terrain features that may be seized by airborne or mechanized forces prior to a large-scale movement. Mud and peat bottoms usually prevent cross-country movement.



Figure 40. Arctic lake region (Northwest Canada).

- (2) Special engineer floating and portable bridging equipment may be necessary to supplement other means of traversing a swampy area or to cross or bypass a gap in a causeway.
- (3) Snow roads may be built over swamps by removing the snow and then pouring water over the cleared surface until a frozen surface is obtained.

85. Information Requirements

Major drainage areas are shown on maps of appropriate size accompanying a terrain study. Textual notes are provided if the important facts cannot be shown adequately on a map. Detailed information on features of military significance along a stream or portions of it may be shown on a strip map or annotated photomosaic. Information requirements may include—

a. Rivers and Streams.

- (1) Name or other identification, and location.
- (2) Channel characteristics.
 - (a) Form (single or braided (fig. 41), straight, meandering, shifting).
 - (b) Length.
 - (c) Profile (crosssection at selected points).
 - (d) Gradient (data on slope of stream bed).
- (3) Bottom characteristics.
 - (a) Composition.
 - (b) Depth and firmness of material.
 - (c) Unusual bottom conditions (logs, stumps, pilings, cables, nets).

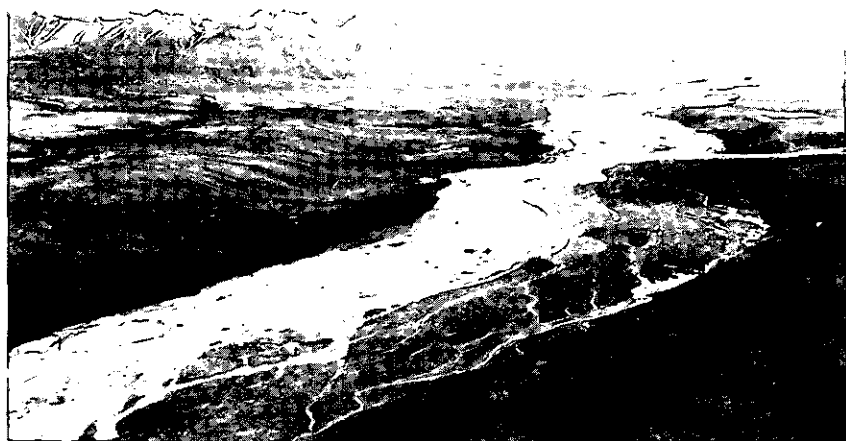


Figure 41. Characteristic braided stream drainage pattern (subpolar Canada).

- (4) Flow characteristics.
 - (a) Measurements and periods of occurrence at low, high, and mean water of depth, width, volume of discharge, and velocity (minimum, maximum, and mean).
 - (b) Special phenomena (crosscurrents, undertows, eddies, floods); periods; area covered; destructive effects. Tidal effects at low, high, and mean tides.
 - (5) Physical and chemical characteristics of water (turbidity, color, odor, taste, temperature, chemical composition, bacterial pollution, seasonal variations).
 - (6) Bank characteristics (composition, stability, height, and slope).
 - (7) Regulatory structures (levees and dams).
 - (8) Islands, bars, shoals, and rapids (name, size, surface roughness, elevation, and pattern).
 - (9) Ice (earliest, latest, and mean freezing and breakup dates, extent of frozen surface; thickness of ice; carrying capacity; and frequency and location of ice jams).
 - (10) Kind and prevalence of animal and vegetable life.
 - (11) Type and location of crossings.
 - (12) Utilization of watercourse (for water supply, irrigation, disposal of waste).
 - (13) Accessibility for military water supply (relation of road nets to potential water points, off-road approaches, intake problems).
- b. Lakes.*
- (1) Name or other identification, and location.
 - (2) Measurements.
 - (a) Length, width, depth and surface area at low, high, and mean water; periods of occurrence of each.
 - (b) Gage locations and periods of record, zero gage elevations, mean and extreme gage heights and periods of occurrence.
 - (3) Shore characteristics (composition, stability, height, and slope).
 - (4) Physical and chemical characteristics of water (turbidity, color, odor, taste, temperature, chemical composition, bacterial pollution, seasonal variation).
 - (5) Bottom characteristics (composition, depth and firmness of material, unusual bottom conditions, profiles).
 - (6) Regulatory structures.
 - (7) Islands, bars, and shoals (name, size, surface roughness, elevation, and pattern).
 - (8) Ice (earliest, latest and mean freezing and breakup dates; extent of frozen surface; type and thickness of ice; and carrying capacity).

- (9) Kind and prevalence of animal and vegetable life.
- (10) Type and location of crossings.
- (11) Utilization of water body (for water supply, irrigation, disposal of waste).
- (12) Accessibility for military water supply (relation of road nets to potential water points, off-road approaches intake problems).

c. Marshes and swamps.

- (1) Information in *b* above, as applicable.
- (2) Seasonal variations (months when variations in extent and wetness are greatest and least).
- (3) Cross-country movement under various seasonal conditions.
- (4) Existing or potential causeways.
- (5) Special conditions (quicksand, permafrost).

Section IV. NEARSHORE OCEANOGRAPHY

86. Beaches

a. A *beach* is the sloping zone of unconsolidated material bordering a sea or lake, lying between the limits of low and high water (fig. 42). It is also defined as the zone extending from low water landward to a definite change in material or physiographic form, such as a sea cliff or to the line of permanent vegetation.

b. Beaches are characterized according to their predominant surface material, such as sand, silt, cobble, pebble, boulder, or by combinations of these materials, such as sand and pebble. Mud beaches are common, but silt is not usually found in beach form, occurring more commonly in underwater banks and shoals.

c. In general, beaches are long and continuous on low-lying coasts, on shores with soft rock formations, and where there is an abundant supply of material deposited by streams. Along hard-rock coasts and on those not well supplied with stream-carried material, beaches are short and discontinuous, and are usually separated by bold headlands or rock outcrops (fig. 43).

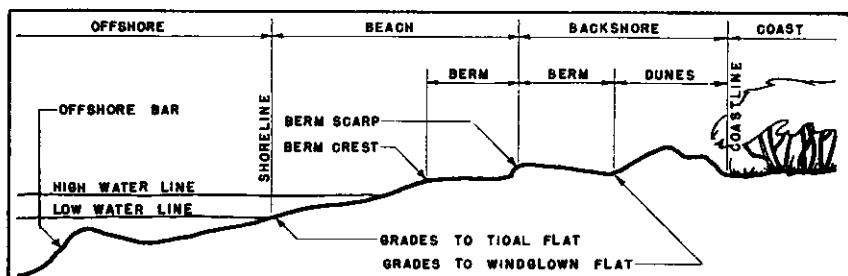


Figure 42. Beach profile diagram.



Figure 43. Characteristic coastline, hard-rock terrain (Brazil).

d. The width of a beach is subject to considerable change. Where there are seasonal variations in wave attack and the supply of material, beaches may disappear or be greatly damaged when the wave attack is heaviest. Beaches formed principally by streams usually show marked seasonal variations in width, and are narrowest during the period of least rainfall. Beach widths are most nearly constant when the beaches are protected by groins or similar structures.

e. The slope of a beach is determined chiefly by the size of the beach material and the intensity of wave attack. Beaches of fine sand that are not subject to intense wave action commonly have slopes ranging from 1 on 5 to 1 on 60. Coarse material under light wave attack results in beach slopes from 1 on 5 to 1 on 10. The band of wave uprush on a beach is a good indication of the slope. On air photographs it may appear as a dark band lying just landward of the waterline. A wide uprush band indicates a flatter slope than a narrow band. On gravel beaches, however, uprush bands are always narrow, and usually do not appear clearly on aerial photographs.

f. There is a wide variation in firmness between different beaches and different parts of the same beach. Beaches are most firm when damp and when the material size is small. Dry sand usually is soft, except when the material size is small. Pebble, cobble, and boulder beaches are firm as far as bearing strength is concerned but are loose, making it difficult for tracked vehicles to cross them. Silt and clay are invariably soft, but combinations of mud and sand provide a hard surface. As a rule, exposed beaches are firmer than similar beaches in sheltered locations.

g. Vegetation on the area immediately in rear of a beach is an indication of stability. Areas with a vegetation cover are firmer than other parts of the beach and always lie above the limit of wave uprush. There is no vegetation on gravel beaches, but beaches composed of gravel and sand in combination may have a vegetation cover.

h. Fresh water is seldom available on undeveloped beaches, although it may be obtained from nearby streams or in completely enclosed pools or lagoons that lie immediately behind the beach. Streams or rivers with steep gradients that cross the beach will provide fresh water at sites above the highest reach of the tide.

87. Adjacent Terrain

a. *Beach ridges* are mounds of beach material heaped up by wave action along the upper limit of wave uprush. They may occur as single ridges or as a series of approximately parallel ridges extending some distance inland. Commonly these ridges reach from 3 to 8 feet above mean high tide, but individual ridges may be as high as 30 feet. High ridges are found only in exposed locations, and are signs of occasionally severe storm wave action. Ridges occur only when

there is an abundant supply of material on or in back of the beach. In some locations belts of beach ridges extend for a mile or two inland, with a vertical difference in elevation of only a few feet. Usually these areas are covered with grass or low bushes.

b. Dunes are formed by windblown sand carried inland from the beach and deposited as irregular hills or mounds. The sand is of fine to medium size. Dunes may reach heights of 300 feet, although commonly they do not exceed 100 feet in height. Where there is vegetation, the dunes are fairly firm and can be crossed by light vehicles. Usually the vegetation consists of low bushes and grass. Fresh water may be obtained from wells sunk in depressions between dunes.

88. Underwater Topography

a. An examination of the terrain as shown in photographs, topographic maps, and hydrographic charts will indicate the probable characteristics of the hydrography. If the land behind the beach is flat and sandy or marshy, the sea bottom close inshore also will be fairly flat. A beach located on a long stretch of regular coastline normally will have one or more sandbars offshore. Large rock outcrops along the beach or close inland indicate that there are probably similar outcrops underwater near the shore. Beaches backed by cliffs or steeply rising hills generally will have a fairly steep underwater gradient.

b. The form of the beach also indicates the underwater contours. A wide, flat beach is an indication of a gently sloping bottom offshore, while a sharp narrow beach suggests a steep slope. Sand beaches have flat to steep slopes, while beaches of gravel, cobble, or boulders are usually steep. It must be remembered, however, that the entire beach profile is changeable, varying with the wave conditions that act upon it. Short concave or pocket beaches (fig. 44) flanked by well-developed headlands are the most constant in their form.

c. The characteristics of the materials that comprise the nearshore bottom are significant in relation to their suitability for the movement of men, vehicles, and landing craft. Bearing strength and smoothness of uniformity are the most important factors. Sand, sand and shell, and gravel bottoms are ideal for landing operations. They are firm and usually quite smooth, although bank, bar, and shoal formations are common. Sand and mud mixtures may be either firm or soft, but they usually are smooth. Mixtures with a high percentage of sand are firm, the firmness decreasing as the sand content is reduced. This type of bottom often has soft spots that may prove hazardous. Mud bottoms are generally avoided, since they are soft, smooth, and slippery. An exception is the case of a thin mud cover overlying a rock bottom, where the rock provides an underlying formation that will give a satisfactory bearing surface if the mud is not more than 1 or 2



Figure 44. Concave beach.

feet thick. Clay bottoms are unsatisfactory, since they are soft and slippery and have little strength.

89. Coral Reefs

a. Reef-building corals are marine animals that remove lime from sea water and deposit it around their living bodies, making hard structures of many types. They do not flourish at temperatures much under 75° F. Consequently coral reefs are found only in tropical waters. Since corals cannot move, securing microscopic food from water moving around them, they are usually found near the edge of reefs, along channels, and out from headlands. They cannot form opposite muddy streams or those with a heavy discharge. If the water movement in coral areas is swift enough, rounded coral heads will predominate, while in more quiet water there usually is an open growth of branching corals. Reef corals cannot stand exposure to the air for more than a few hours, so that their upward growth is limited by the level of mean low water. Most coral reefs belong to one of three types—fringing reefs, barrier reefs, or atoll reefs (fig. 45).

b. A *fringing reef* is attached to the shore. If the wave attack is weak, there will be a gently sloping beach of coral sand. Strong wave attack results in steep gravel, cobble, and boulder beaches. On most fringing reefs there are *boat channels* about 1 to 15 feet deeper than the rest of the reef-flat, from 10 to 50 yards or more wide, and more than a mile in length. These run approximately parallel to the land, opening into breaks in the reef, and providing convenient waterways for small craft.

c. *Barrier reefs* are located roughly parallel to the coastline at some distance offshore. Whether or not a craft can cross a barrier reef depends upon the depth of the coral below water. Usually the coral

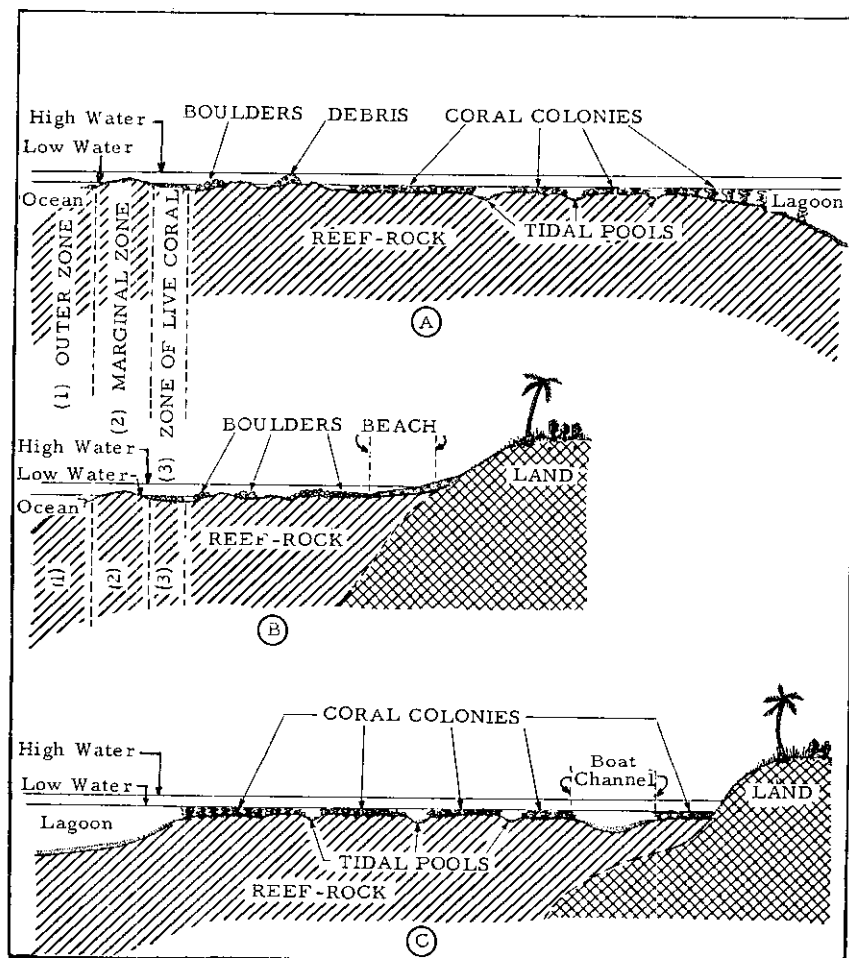


Figure 45. Barrier and fringing reefs—diagrammatic cross-sections. (a) Wide barrier reef. (b) Narrow, exposed fringing reef. (c) Protected fringing reef. (Not drawn to scale.)

surface is about 6 inches above mean low water, but it may be deeper. Walking upon the reef is dangerous, since the reef-flat is seldom above water and the holes between coral colonies are irregularly spaced, deep, and lined by jagged coral. At low water, extensions of the reef into the lagoon behind it may create compartments that hinder or prevent the free movement of craft along the reef.

d. *Atoll reefs* (fig. 46) are more or less complete rings of coral enclosing circular lagoons.

- (1) The marginal zone of the reef is a strip from 25 to 75 yards wide, across which a belt of surf moves with the rise and fall of the tide. If the outer, seaward slope of the reef is steep, there is a clear approach for landing craft. A gentle slope

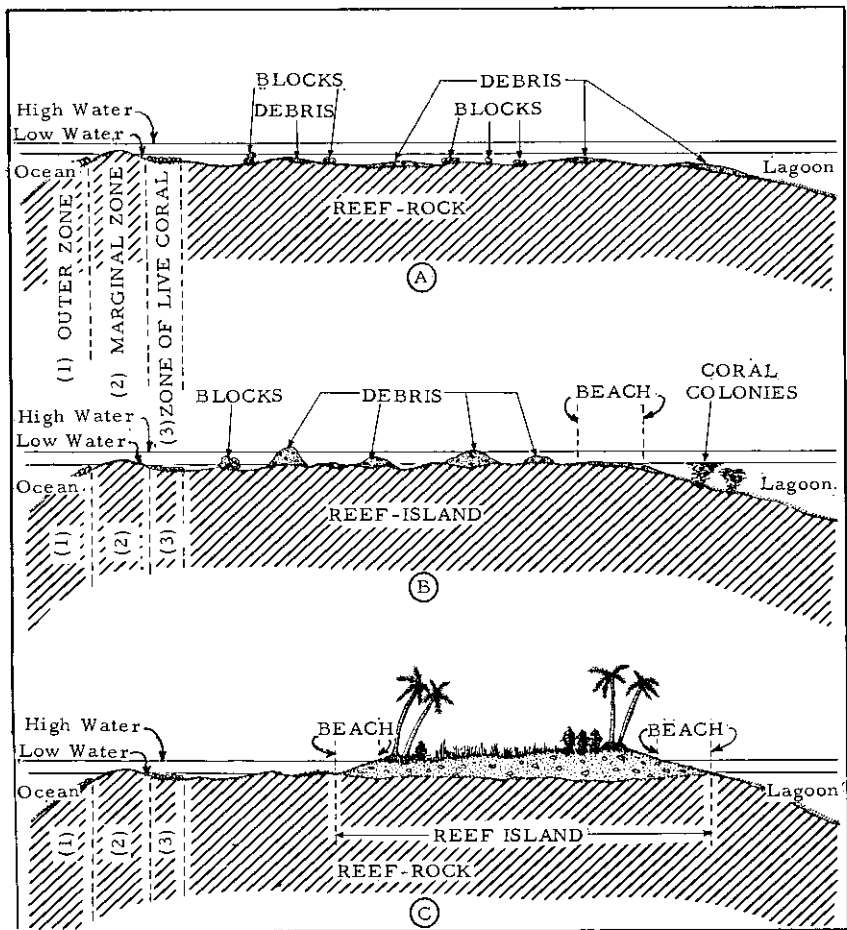


Figure 46. Atoll reefs—diagrammatic cross section (a) Open-reef area. (b) Area of impermanent debris accumulation. (c) Reef-island area. (Not drawn to scale.)

will have coral heads growing just outside, making an approach dangerous. At high tide it may be possible to cross the marginal zone by boat.

- (2) Reef islands usually are located on higher parts of an atoll reef. These are fairly permanent accumulations of debris which may contain vegetation, including coconut trees. Typically these islands are surrounded or partly surrounded by a beach 10 to 50 feet or more wide, consisting of coral sand and organic debris. Reef islands are seldom more than 10 to 15 feet higher than the reef-flat, and their interiors usually are flat and featureless.

- (3) From the viewpoint of landing operations, the most unfavorable feature of an atoll reef is the high, surf-covered marginal zone. Surf intensity is less on the leeward side. On the lagoon side by entering through channels or breaks in the reef, craft may land on the sand beach at high water. Crossing the reef-flat at low tide is impracticable.

90. Military Considerations

a. Reference. The effects of nearshore oceanography and the coast upon amphibious operations are discussed in field manuals of the 60-series.

b. Coastline.

- (1) In general, coastlines are concave, convex, straight, or irregular.
- (2) A *concave* coastline forms a reentrant into the coast. From the flanks, converging fires may be brought upon landing forces. Accordingly, the first efforts of an attacker are directed toward neutralizing or securing the flanking promontories by means of subsidiary landings, airborne landings, naval gunfire, and aerial bombardment.
- (3) The *convex* type of shoreline includes gently outcurving shores, points, capes, and peninsulas. Supporting fires may be placed on the defender from his flanks and, occasionally, from his rear. His routes of withdrawal or reinforcement are restricted, and his position may be isolated by a landing at the base of the promontory. It is difficult for the defender to organize his fires and to secure extensive fields of fire. Convex shorelines are more exposed to currents, winds, and surf and are often steep and rocky, making landing difficult.
- (4) A *straight* shoreline has no prominent indentations or promontories. It offers no decisive advantage either in attack or defense. Very few coastlines, however, are so straight that they provide no positions for flanking fires.
- (5) An *irregular* coastline is a complex of concave and convex shorelines.

c. Reefs. Barrier and atoll reefs may be obstacles at a distance from the landing beach. A fringing reef forms a nearshore obstacle, normally with a rough tablelike surface, that extends seaward from the shoreline at a level slightly above or below the water. A wide fringing reef provides an area well suited to the organization of defensive small-arms fires.

d. Offshore Islands. Frequently shorelines are protected by groups of small islands lying so close to the mainland that they form a complicated system of waterways immediately offshore. If the defender organizes the more important islands, he can bring fire upon an attack-

ing force from many directions. Routes of approach to the mainland through the islands may be tortuous and restricted, making an approaching landing force highly vulnerable throughout its shoreward movement. These islands may be neutralized with nuclear weapons or may be isolated and reduced in detail by successive minor landings preceding the main amphibious attack. Once secured, they provide the attacker with favorable artillery positions to support the landing.

91. Information Requirements

Terrain studies made for planning amphibious operations are very detailed. Normally they are based upon the complete data that is provided by strategical studies and major sources such as the National Intelligence Survey. In general, the following items represent the fundamental information requirements about a proposed landing area:

a. Location.

- (1) For a beach 2 miles or more in length, the latitude and longitude of its limits; for a beach less than 2 miles long, of its center.
- (2) Nearness to objective of the operation, if known, and to developed areas such as water terminals, harbors, and adjacent beaches.

b. Sea Approach.

- (1) Landmarks, both natural and manmade.
- (2) Hydrography (nearshore and offshore depths; flats (tidal or other), character of the material and its bearing strength; length of and depths over reefs, bars, shoals, or other natural obstructions; anchorage areas and their conditions; character of nearshore bottom material).
- (3) Tides and currents (tidal rise and fall, local peculiarities, direction and magnitudes of currents; neaps and springs).
- (4) Winds (strength, direction, effect on tidal heights and surf, local peculiarities).
- (5) Waves and surf (height and period of offshore waves; intensity).

c. Beach.

- (1) Material (type and size, firmness, variability with weather or season, subsurface material).
- (2) Gradient (note particularly scarps and ledges).
- (3) Beach structures (groins, bulkheads, jetties, submerged remains of former structures).
- (4) Rivers and streams (variability in beach character where rivers cross beach; river channels).
- (5) Effects of weather conditions upon trafficability of beach.
- (6) Local use of beach.

- (7) Sources of fresh water on or near beach (both potable and nonpotable).

d. Terrain Inland or on Flanks.

- (1) Topography (topographic features, waterways, swamps or marshes, vegetation, location and size of possible dump or assembly areas).
- (2) Exits (existing exits by roads or trails; cross-country exits; roads, with details of width, surface, construction; railways, tramways).
- (3) Aircraft landing sites within a 10- to 15-mile distance from beach (dimensions, surface, topography).
- (4) Utilities (communications, electricity, water supply, transportation).

Section V. SURFACE MATERIALS

92. Soil

a. General.

- (1) *Soil* is defined as the unconsolidated material that overlies bedrock. Soil is made of disintegrated rock, in the form of sand or clay, and humus, the disintegrated remains of past vegetation.
- (2) Detailed information about soils, their engineering properties, and testing techniques is contained in TM 5-541 and TM 5-530.

b. Classification. For field identification and classification, soils may be grouped into five principal types: gravel, sand, silt, clay, and organic matter. These types seldom exist separately but are found in mixtures of various proportions, each type contributing its characteristics to the mixture.

- (1) *Gravel* consists of angular to rounded, bulky mineral particles ranging in size from about $\frac{1}{4}$ inch to 3 inches in diameter. It is classified as coarse or fine; well or poorly graded; and angular, flat, or rounded. Next to solid bedrock, well-graded and compacted gravel is the most stable natural foundation material. Gravel is easy to drain, easy to compact when well graded, affected little by moisture, and not subject to frost action.
- (2) *Sand* consists of mineral grains ranging from about $\frac{1}{4}$ inch down to about .003 inch in diameter. It is classified according to size and gradation as coarse, medium, or fine; and as being angular or rounded. Well-graded angular sand is desirable for concrete aggregate and for foundation material. It is easy to drain, little affected by moisture, and ordinarily not affected by frost action. Sand provides an excellent road

subgrade material when it is confined. Care is required, however, to distinguish between a fine sand and silt.

- (3) *Silt* consists of natural mineral grains which will pass a No. 200 sieve. It lacks plasticity and possesses little or no cohesion when dry. The term *rock flour* is commonly used to describe inorganic silts of glacial origin. All silts are treacherous, both for trafficability and as a foundation material. Because of its inherent instability, slight disturbances in the presence of water, such as traffic vibrations transmitted to a wet silt subgrade, will cause the silt to become soft or to change to a "quick" condition. When ground water or seepage is present, silts exposed to frost action are subject to intensive ice accumulation and consequent heaving. Silts are difficult to compact and drain.
- (4) *Clay* generally consists of particles smaller than .0002 inch, microscopic in size. Its plasticity and adhesiveness are outstanding characteristics. Depending upon the proportion of coarser grains, clays vary from lean clays (low plasticity) to fat clays (high plasticity). Many clays which are brittle or stiff in their undisturbed state become soft and plastic upon being worked.

Soil Maps.

- (1) Soil maps or overlays indicate the predominant soils in given areas, identifying them according to their engineering characteristics. Such maps may be constructed from air photographs or ground reconnaissance. They also may be made from existing soil and geologic maps and reports, with the classifications expressed in engineering terms. Agricultural soil maps seldom are large enough to provide sufficient detail for tactical planning. On many of them, the designated soil type applies only to the surface soil.
- (2) Soil maps should indicate the following properties of soils:
 - (a) Permeability.
 - (b) Stability under stress.
 - (c) Bearing capacity.
 - (d) Important variations of (b) and (c) above with changing moisture content.
- (3) For strategical planning, soil maps should cover large areas. The greatest possible amount of general information should be presented, since the detailed plans are not firm and the probable weather conditions are unknown. The reliability of the information must be clearly indicated. Information should be given concerning the effects of various weather conditions upon the soils.

- (4) Soil maps for tactical planning cover a smaller area than strategical soil maps. They are of a larger scale and contain more precise, detailed information. Greater accuracy is possible because more details are known about the proposed operations. Reconnaissance and patrol reports make it possible to check the ground, and weather forecasts are available to indicate what the prevailing weather will be. The information contained on such maps is useful in determining—
 - (a) Areas critical to cross-country movement as they affect both advances and counterattacks.
 - (b) Stretches of road liable to failure under heavy traffic.
 - (c) Suitable and unsuitable areas for airfields, field fortifications, and other installations.
 - (d) Areas with soil conditions that are unsuitable for tank and vehicle parks.
 - (e) Difficult areas for field and air defense artillery deployment.
 - (f) River bank conditions for bridge foundations and crossing operations.
- (5) In planning rear area activities, soil maps are useful for such purposes as the following:
 - (a) *Determining road conditions.* In order to stand up under heavy traffic during periods of frost and thaw, a road must have a well-drained subsoil foundation. A knowledge of the soils in an area will reveal which stretches of road will be most susceptible to breakdown during a thaw, providing a guide to selecting the best supply routes and indicating portions of the road where precautions must be observed. When supplemented by an aerial reconnaissance, soil maps are a valuable aid in highway location and relocation. They indicate the soil areas with desirable or undesirable engineering characteristics and also show the nearest sources of materials for road construction and maintenance.
 - (b) *Locating installations.* The information about soil conditions given by a soil map is invaluable in selecting sites for airfields, storage installations, ammunition dumps, and vehicle parks. Preliminary study of the map prevents unnecessary field reconnaissance.

d. Military Considerations.

- (1) *General.* The actual identity of the type of soil in any area is of little practical value unless the soil is also evaluated in relation to the existing or predicted weather. In general, the major soil types have the following characteristics:

- (a) *Gravel.* Weather has little or no effect on the trafficability of a gravel soil. Gravel offers excellent trafficability for tracked vehicles. If it is not mixed with other soil, however, the loose particles may roll under pressure, hampering the movement of wheeled vehicles.
 - (b) *Sand.* When wet enough to become compacted, or when mixed with clay, sand gives excellent trafficability. Very dry, soft, or loose sand is an obstacle to vehicles, particularly on slopes.
 - (c) *Silt.* When dry, silt provides excellent trafficability, although it is very dusty. Silt absorbs water quickly and turns to a deep, soft mud when wet, imposing a definite obstacle to movement. It dries quickly after a rain, soon becoming trafficable again.
 - (d) *Clay.* When thoroughly dry, clay provides a hard surface with excellent trafficability; however, clay is seldom dry except in arid climates. While clay absorbs water very slowly during a rain, it also takes a long time to dry. Wet clay is very sticky and slippery. Slopes with a clay surface are difficult or impassable, and deep ruts form rapidly on level ground. A combination of silt and clay makes a particularly poor surface when wet.
 - (e) *Special soil conditions.* Regardless of type, if a soil has underlying bedrock near the surface, it will become thoroughly saturated after a rain. The water cannot drain away, making the surface untrafficable.
- (2) *Manmade effects.*
- (a) Soil under cultivation because it has been worked is softer and absorbs water more quickly than other soils and may therefore have poorer trafficability. Usually the presence of irrigation structures indicates that the soil is soft and contains water and the soil generally will have poor trafficability.
 - (b) The type of crops cultivated in an area provide indications as to the nature of the soil. Since gravelly soils are especially suitable for fruit orchards, for example, the presence of extensive orchards, especially on flat areas, may indicate that the soil has a high gravel content. Many cultivated plants have specific soil and water requirements, giving a clue to the soil and drainage of the area. TM 5-545 discusses the characteristics of various plants as soil type indicators.
- (3) *Nuclear weapons.* Soil composition and density affect the amount of damage by shock that will result from a surface or subsurface burst. Propagation of the shock wave is poor-

est in light, loamy soils and best in plastic, wet clay. The pressures transmitted by such soil may be 50 times greater than those transmitted through sandy clay. Craters and induced radiation in the soils are results of the bursts also.

e. Information Requirements. In a terrain study, soil information usually is presented in tabular form, with the data keyed to a soil map or overlay. It covers—

- (1) Extent of each dominant soil type.
- (2) Depth of each type in areas indicated.
- (3) Surface texture (fine or coarse).
- (4) Parent material.
- (5) Description of material.
- (6) Properties when wet, dry, or frozen, including—
 - (a) Suitability for specified military vehicles under various conditions.
 - (b) Bearing capacity for structure foundations.
 - (c) Permeability when wet.
- (7) Variations from dominant soil type in specified areas.
- (8) Areas of permafrost, permanent ice and snow.
- (9) Seasonal state of the ground (dry, wet, flooded, frozen, snow-covered) by seasons, months, or shorter periods. Effects of each state on cross-country movement, construction, excavation, cover and concealment, and other military aspects.

93. Rock

a. Definitions and Classification. *Rock* may be defined as the firm and coherent or consolidated material of the earth's crust. *Bedrock* is solid undisturbed rock either exposed at the surface or underlying the soil. The three major classes of rock are *igneous*, *sedimentary*, and *metamorphic*. *Igneous* rock is formed by cooling and solidification from a molten or partly molten state; *sedimentary* rock, from material accumulated as a deposit from water or the air, and *metamorphic* rock, by the recrystallization of igneous or sedimentary rock under the influence of heat, pressure, or both. The information, characteristics, and uses of rock are explained in TM 5-545.

b. Underground Installations.

- (1) Underground installations require rock and soil that are easily worked and locations that are accessible to transportation and power facilities. Plains, terraces, and alluvial fans usually are best for bunker type installations. The most favorable terrain for tunnels normally is found on plateaus, escarpments, high hills, and mountains with steep bare-rock surfaces.
- (2) Large bunkers require deep, well-drained soils, with the water table at least 15 to 20 feet below the surface. They

should be protected against surface-water flooding, especially if they are located on low plains.

- (3) Military tunnels may be constructed for tactical, communication, storage, and shelter purposes, including—
 - (a) Undermining enemy positions and countermining.
 - (b) Galleries for water supply.
 - (c) Fortifications (headquarters, gun emplacements, ammunition storage, defensive installations).
 - (d) Underground factories and hangers.
- (4) Before tunneling operations are initiated, a geologist should evaluate the proposed site. Tunnel type installations are favored by high, steep slopes of exposed bedrock. The tunnel is kept dry by placing the lowest levels above the water table and by constructing it in rocks that have a minimum of fissures, joints, and faults that would permit seepage and flooding. The size of the chambers depends upon the stability of the rock. The thickness of natural cover required to give adequate protection depends upon the type of rock and soil, degree of soundness of the rock, absence of joints and fissures, and the size and shape of the underground openings.

c. Information Requirements. Terrain studies of an area will be concerned chiefly with the availability of unexploited natural deposits suitable for the construction of roads, protective works, airfields, and underground shelters. The particular information that will be required depends upon the purpose of the study. Fundamental information requirements may include—

- (1) *Rock deposits.*
 - (a) Location and extent of deposit.
 - (b) Type and properties of the material.
 - (c) Suitability for construction use (as aggregate, binder, surfacing, ballast, riprap, masonry construction material).
 - (d) Accessibility.
- (2) *Underground shelters.*
 - (a) Existing areas (mines, caves, underground manmade installations). Characteristics.
 - (b) Areas suitable for development (rock structure, comparative advantages and disadvantages of indicated locations).

Section VI. VEGETATION

94. General

a. Vegetation may be classified in four broad categories—trees, shrubs, grasses, and cultivated crops.

b. The type of vegetation in an area gives an indication of the climatic conditions, soil type, drainage, and water supply. Seasonal

seepage or a rise in the ground-water supply often is indicated by vegetation such as reeds, sedges, cottonwoods, and willows, which thrive wherever seepage occurs. Similarly, arid conditions are also indicated by characteristic desert vegetation. TM 5-545 describes the indications typical of various plant species.

95. Trees

a. Definitions.

- (1) *Trees* are defined as perennial woody plants at least 10 feet in height, with single stems and definite crown shapes. A forest is an extensive area covered by trees growing in a close formation, so close that in most cases their crowns touch. Smaller areas covered by trees may be termed *woods*, *groves*, or *woodlots*. In the terminology used on U.S. Army maps, any perennial vegetation high enough to conceal troops or thick enough to be a serious obstacle to free passage is classified as *woods* or *brushwood*.
- (2) Commonly, a *deep woods* is considered as one that is large enough to provide ample concealed maneuver space for large units deployed in depth. This would include, for example, a woods that would conceal both the assault and reserve echelons of a battle group in the attack. A *shallow woods* is one that is not large enough to conceal elements of this size. *Dense woods* are those where the growth is thick enough to interfere with visibility sufficiently to limit the maneuver of troops.

b. *Characteristics.* Trees are commonly found in temperate regions at elevations of not more than 8,000 feet above sea level. A good forest climate is one with a warm, rainy vegetative season, a continually moist subsoil, and low wind velocity. The growth of trees is greatly influenced by the temperature of the air and soil; even the hardiest conifers require a mean warm month temperature of at least 50° F.

c. Classification.

- (1) Trees are classified as either *deciduous* or *evergreen* (fig. 47). Deciduous trees drop all their leaves seasonally, while evergreen trees retain their leaves throughout the year. Trees are also either *needleleaf* or *broadleaf*.
- (2) In the middle latitudes, needleleaf trees are predominantly evergreen, and broadleaf trees are predominantly deciduous. In the humid tropics, nearly all trees are evergreen because the climate remains uniform throughout the year. Almost all deciduous forests are located in the Northern Hemisphere.
- (3) The classification of forests according to their influence on nuclear weapon effects is presented in (C) TM 23-200.



Figure 47. Mixed vegetation, showing: (a) evergreen trees, (b) deciduous trees, (c) brush, and (d) sedges. (Northern Manitoba.)

d. Critical Dimensions. The important dimensions of trees in a wooded area are the diameter of the tree stems at breast height, the average height of the trees, and the average height above ground of the lowest branches.

e. Low-Latitude Forests. In the low latitudes, *tropical rain forests*, *moss forests* and *swamp forests* are the principal types.

(1) *Tropical rain forests.*

(a) In the tropics, rain forests (*selva*) blanket many square miles of moist low lands in regions where rainfall is heavy and well distributed throughout the year, with no marked dry season. The Amazon Basin and West Central Africa are the two largest areas of tropical rain forest, although it is also found along many rainy coasts and on tropical islands. This type of forest covers more than one-tenth of the earth's total land surface and comprises nearly one-half of the total forest areas of the world.

(b) The rain forest consists of virgin growth, composed of mature broadleaf trees of many species that form a canopy thick enough to shut off most sunlight. The trees are commonly from 100 to 150 feet in height, with large diameters, smooth trunks, and few lower branches. *Lianas*, ropelike plants that entwine themselves around trunks and branches, are common. Usually the undergrowth is not dense, although it restricts observation. In the deepest shade, there is usually only a thick mat of ferns or herbs that offers no obstacle to movement. Typical jungle conditions, with thick and impenetrable undergrowth, are characteristic chiefly of sections where light reaches the

forest floor, as on precipitous wet slopes, along rivers and coasts, and in abandoned agricultural clearings.

- (2) The *tropical swamp forest* (figs. 48 and 49) occurs in low terrain near or in swampy regions. Mangrove swamp forests (fig. 50) cover large areas along tropical salt-water coasts, presenting an almost impenetrable barrier to movement. This type of forest is found in the soft mud around river mouths, deltas, and inlets, along shallow bays on small islands, and upstream as far as the tidal influence is felt. Mangrove forests include several kinds of trees, all with thick buttressed roots that extend as high as 10 feet above the ground. These spread outward, becoming interlaced in a network that makes movement by foot almost impossible and prohibits any type of vehicular movement. Nipa palms, which generally grow in or near mangrove swamps, also present almost impassable barriers (fig. 51).
- (3) *Moss forests* are found in the higher latitudes just above the rain forest areas, chiefly at altitudes of 3,000 feet or higher on the tops of tropical mountains wherever high humidity and cloudiness are persistent. The trees are small with long overhanging branches. Moss grows on the branches, tree trunks, and ground, where it is intermingled with ferns and vines to form a blanket that conceals the earth. This moss often covers chasms and ravines, making them appear to be level terrain. The moss forest accordingly is hazardous to movement. It is dark and gloomy and so dense that very little sunlight penetrates the canopy. Visibility is extremely limited.



Figure 48. Swamp forest (air view) (Sanibel National Wildlife Refuge, Florida).

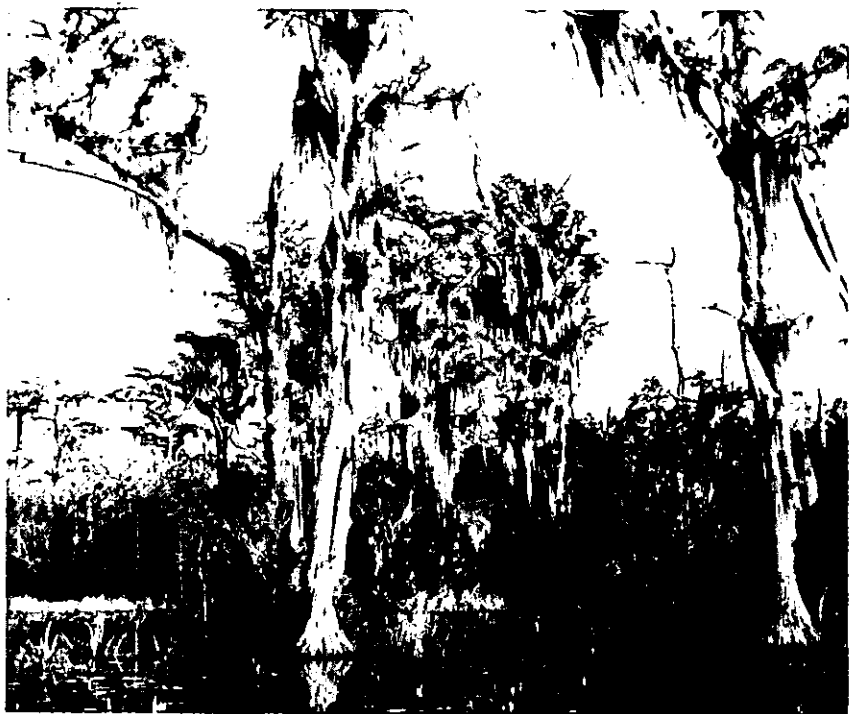


Figure 49. Swamp forest vegetation (Okcefenokee Swamp, Georgia).



Figure 50. Mangrove swamp (Malay Peninsula).



Figure 51. *Nipa* palms (Northern New Guinea).

f. Middle-Latitude Forests. The principal forest types in the middle-latitudes include *Mediterranean scrub forests*, *broadleaf forests*, and *coniferous forests*.

- (1) *Mediterranean scrub forests* consist of broadleaf evergreen trees adapted to regions with long, hot periods of summer drought. They are found in the borderlands of the Mediterranean Sea, as well as in California, Chile, southern Australia, and the Capetown region of Africa. These areas are subtropical, with mild, rainy winters and long, dry, hot summers. This type of forest consists of low trees and woody shrubs. Where climate and soil conditions are most favorable, the virgin forest is composed of low, widely spaced trees with massive trunks and gnarled branches. Between the trees the ground is completely or partially covered by a pale, dusty bush and shrub vegetation resembling the soil in color. Cork oaks and olive trees are typical of this type of forest.
- (2) Most of the temperate *broadleaf forest* is composed of deciduous trees with a seasonal leaf fall, such as oak, hickory, maple, ash, elm, walnut, beech, and poplar. Along the humid subtropical margins of the middle latitudes, principally in

southern Japan, New Zealand, and southeastern Australia, there are evergreen broadleaf forests that resemble rain forests, with dense undergrowth and heavy vines. Temperate broadleaf forests vary widely in composition, the dominant tree species differing from one region to another. In some areas there are many conifers among them and the forest may be described as *mixed*.

- (3) *Coniferous* trees are almost exclusively evergreen. The growth and discard of the needles is a continuous process not confined to any particular period or season. Usually the coniferous forests occupy the colder continental locations on the poleward side of the broadleaf forests. In areas of poor sandy soils, or on steep mountain slopes where soils are thin or rocky and temperatures are lower, conifers may supplant broadleaf trees even in the middle latitudes. South of the great belts of subarctic conifers there are large areas of coniferous trees that provide valuable timber, such as the forests of the Pacific Coast, western Canada, and Alaska. The southern pine forests in the Atlantic and Gulf Coastal Plains of the United States also are major sources of timber.

g. High-Latitude Forests. A wide belt of conifer forests, the *taiga*, extends from coast to coast in the subarctic regions of Eurasia and North America below the treeless tundra regions. The Eurasian taiga is the largest continuous forest area in the world. Conifers such as fir, spruce, larch, and pine predominate, although in the swamp areas there are some deciduous trees such as aspen, willow, birch, or mountain ash. The area has short, cool summers and long, dry, cold winters so that growth is slow, and few trees are more than 1½ feet in diameter. There are numerous large swamps and marshes covered with sphagnum moss and containing such trees as balsam and spruce. These areas usually become impassable rapidly after precipitation or during a thaw.

96. Shrubs

a. Definition. *Shrubs* are woody plants usually less than 10 feet high with more than 1 stem. They include a variety of trees that have had their growth stunted because of soil or climatic conditions. *Scrub growth* includes cactus, stunted shrubs, sagebrush, mesquite, and similar plants found most frequently in arid or semiarid areas.

b. Characteristics. Shrubs comprise the undergrowth in the open forests of middle latitudes. In many arid and semiarid areas they are the dominant vegetation. They are prevalent in the subarctic and in large, burned-over or cutover areas in humid regions.

c. Classifications.

- (1) Shrubs, like trees, are either deciduous or evergreen needle-leaf or broadleaf. In the middle latitudes, most broadleaf shrubs are deciduous, and all needleleaf shrubs are evergreen. In the humid tropics, nearly all shrubs are evergreen.
- (2) Most arid regions of both low and middle latitudes have some vegetation, both deciduous and evergreen, although it is sparse (fig. 52). It may consist of low bunch grass with widely spaced bushes or fleshy, water-storing plants such as the cacti. Most commonly, the vegetation comprises sagebrush and similar scrub growth. Perennial shrubs of the desert areas grow far apart, with considerable areas of bare soil in between due to the low rainfall. The rate of growth is very slow.

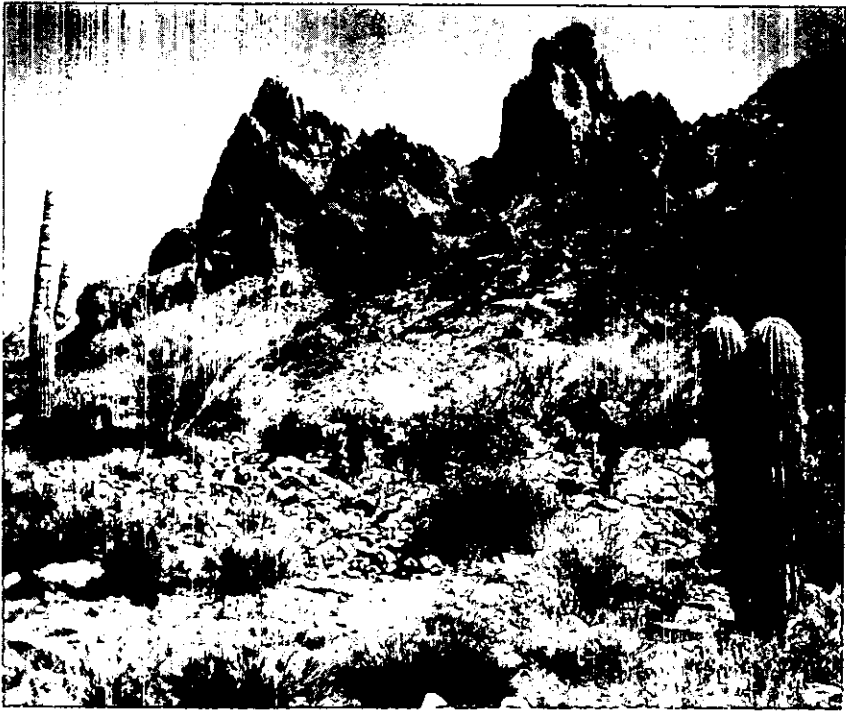


Figure 52. Characteristic desert vegetation (Arizona).

97. Grasses

a. Definitions. Grasses include all kinds of nonwoody plants. A grassland is an extensive area where the natural vegetation consists primarily of grass. In low latitudes, grasslands often are termed *savannas*; in middle latitudes, *prairies* (tall grass) and *steppes* (short

grass). Grasslands in wet or poorly drained areas commonly are called *meadows*.

b. Classification. For terrain intelligence purposes, grass more than 3 feet high is considered tall, and below that height, short.

c. Tropical Grasslands (Savanna).

- (1) In areas with heavy summer rains and a distinct dry season, the grasslands or *savanna* are composed mostly of tall, very coarse grasses that grow in tufts separated by intervals of bare soil. If there are trees, they usually are species that can withstand seasonal drought and they grow mostly in clumps in the grasslands or along the margins of streams.
- (2) Savanna grass grows rapidly at the beginning of the rainy season, reaching heights of 4 to 12 feet in a few months. When dry, the blades become brown, stiff, and harsh in texture, burning very readily. The grasses usually diminish in height with decrease in the annual rainfall, and trees become fewer until under semiarid conditions nearly treeless steppes, composed of shorter grasses, are prevalent. Low-latitude savannas are usually located between desert and forest regions.

d. Middle-Latitude Grasslands.

- (1) *Prairie.* The prairie type of grass occurs most frequently in areas where the soil remains moist for a depth of 30 inches or more. The prairies are covered with tall, luxuriant, and relatively deep-rooted grasses that grow to heights of from 1 to 3 feet. Over most prairie regions, rainfall varies between 20 to 40 inches annually. Usually there is a large variety of flowering plants in spring and summer. The principal prairie regions include parts of central United States and the prairie provinces of Canada; the Argentine Pampa, Uruguay, and southeastern Brazil; the plains of the Danube in Hungary and Rumania; and parts of Manchuria and southern Russia.
- (2) *Steppe.* A steppe is an area of short, shallow-rooted grasses typical of semiarid regions where the depth of moist soil is less than 2 feet. In common usage, the word steppe is used to describe all the drier, short-grass grasslands, both in tropical and middle latitudes. Some of the steppe grasses lie in a soft, fine mat on the ground, while others stand as hard, wiry tufts. Thorny shrubs and low, coarse bushes may dominate the steppe in some sections. Cacti and other succulent plants may be numerous. Steppe vegetation develops typically in regions that receive less than 20 inches of rainfall a year, with a hot summer and a cold, dry winter.

98. Cultivated Vegetation

a. Field crops constitute the predominant class of cultivated vegetation. Vine crops and orchards are common but not widespread, and tree plantations are found only in relatively few areas. The size of cultivated areas ranges from paddy fields covering a quarter of an acre to vast wheat fields extending for thousands of acres. In a densely-populated area, where all arable land is cultivated, each parcel will be used for the crop that brings the highest yield, making it possible to predict the nature of the soils from information about the predominant crops. Rice, for example, requires fine-textured soils. Other crops generally must have firm, well-drained land.

b. An area of orchards or plantations usually consists of rows of evenly spaced trees, showing evidence of planned planting that can be distinguished on an aerial photograph (fig. 53). Usually such an area is free from underbrush and vines.

c. Rice fields are flooded areas surrounded by dikes or walls approximately $1\frac{1}{2}$ to $3\frac{1}{2}$ feet in height and $1\frac{1}{2}$ to $4\frac{1}{2}$ feet wide. When flooded for planting, the depth to the bottom mud ranges from 6 inches to 3 feet.



Figure 53. Citrus orchard (Venice, Florida).

99. Effects on Military Operations

a. Movement.

(1) Trees.

- (a) In most wooded areas, individual trees large enough to stop a tank are seldom so close together that they cannot be bypassed. Closely-spaced trees usually are of relatively small diameters and can be pushed over by a tank. The smaller trees and undergrowth, however, may be so dense that when they are pushed over the resulting mass of piled-up vegetation will stop the tank. In most cases, wooded areas slow down the movement of tanks, and a guide may be required to lead each vehicle because of hidden obstacles. Cutover portions of wooded areas usually contain stumps hidden in tall grass or weeds that are serious obstacles to armor.
- (b) Trees that can stop a wheeled vehicle usually are too closely spaced to be bypassed. The pileup effect from pushing over vegetation is greater for wheeled vehicles than for tanks. Guides to watch for obstacles must be provided. Trailed loads are difficult to tow through wooded areas.
- (c) Woods slow down the movement of dismounted troops. Some types of vegetation, such as mangroves or dense jungle, are frequently impenetrable until routes are cleared.
- (d) Fire lanes often canalize movement through forest areas. The characteristics of certain types of vegetation also canalize movement. This is true when lines of trees border streams, for example.
- (2) *Shrubs and grasses.* Normally, no serious obstacle to movement is offered by shrubs and grasses.
- (3) *Cultivated vegetation.* The type of crop determines the effects of cultivated vegetation upon cross-country movement. Small grain crops hold soil nearly as well as grasses, so that movement is better in such areas than in those planted with row crops. Vineyards present a tangled maze of poles and wires that constitute a definite obstacle to vehicles and dismounted troops. The terraces and retaining walls on hill-sides are also obstacles. Wheeled vehicles and some tracked vehicles are unable to cross flooded paddy fields, although they can negotiate them when the fields have been drained and the soil is thoroughly dry.

b. Observation.

- (1) The height and density of the trees and other vegetation largely determine the amount of ground observation that can

be obtained. To secure an adequate field of view from an observation post, it may be necessary to clear away the vegetation that interferes, at the risk of losing concealment.

- (2) The effects of cultivated crops upon observation vary with seasonal conditions. In 2 or 3 weeks a cornfield may be covered with high stalks that greatly limit observation. Later in the season, the corn may be harvested in a day, providing observation again.

c. Concealment and Cover.

- (1) Thick forests of deciduous trees in leaf give excellent concealment from air observation when troops observe proper precautions in camouflage and movement. Evergreen forests will provide concealment throughout the year, changing color very slightly from season to season. Deciduous trees lose their leaves, reducing concealment, and change color, which increases the difficulty of natural camouflage. Usually undergrowth and small trees growing closely together give better concealment from ground observation than a stand of larger trees. Unless the undergrowth is high, however, it will provide little concealment from aerial observation.
- (2) The amount of concealment and cover provided by cultivated crops depend largely upon seasonal conditions. Disruption of the agricultural pattern is readily apparent to aerial observers and in aerial photographs.

d. Effectiveness of Fire.

- (1) Lanes may be cut through vegetation to provide fields of fire, but it is seldom practical to cut lanes that extend far enough to provide long-range observed fires. Extensive clearing reduces the amount of concealment and indicates the location of weapon positions to the enemy. The extent of clearing that is practicable will depend upon the amount of vegetation, its density, and the length of time that the positions will be occupied.
- (2) Indirect fire is less affected by vegetation than direct fire. Mortars require little more than overhead clearance. Artillery weapons require more clearance than mortars, but high angle fire may be employed to avoid extensive cutting and clearing.
- (3) Air defense artillery can be employed effectively in forests and areas of heavy vegetation when the clearance requirements are accomplished.
- (4) Forests and heavy vegetation may be set on fire as a tactical weapon, particularly during dry seasons. Bivouac areas must be selected with great care, and strictly supervised fire warning and evacuation procedures must be established.

- (5) Wooded areas and those covered with heavy vegetation tend to increase the persistence of gas and smoke, particularly during wet seasons or periods of high humidity.
- (6) The influence of forests and heavy vegetation upon nuclear weapons effects is subject to many variable factors. These include the amount of overhead cover, density of growth, kind of trees (coniferous or deciduous), and the nature of the tree crowns, undergrowth, and litter on the forest floor. Trees in leaf offer a high degree of protection from thermal radiation effect if the cover is sufficiently continuous. Protection from initial nuclear radiation is insignificant. The blast effect knocks down trees, making the forest area a serious obstacle to movement and a danger to troops. In dry seasons, nuclear weapons may start forest fires over wide areas.
- (7) More effective toxic chemical agent cloud concentrations can be built up in heavily wooded or jungle areas than in open terrain. Liquid chemical contamination is generally more effective when agents are dispersed on vegetation than when they are dispersed on barren terrain. Jungle or heavily wooded areas, on the other hand, tend to reduce the effectiveness of biological agent aerosols because of impaction of the agent on tree and leaf surfaces. Reduced air currents in such areas also tend to limit the area coverage obtained.

e. Tactical Effects.

- (1) *Attack.* Woods provide concealment and cover for assembly areas and during the approach march. Forests and heavy vegetation, however, increase the difficulty of maneuver in advancing to attack and in launching the assault. The attacker may have little or no information about the roads, trails, and topography in the area not under his control, due to the difficulty of securing detailed terrain intelligence without actual reconnaissance.
- (2) *Defense.* Wooded and heavily vegetated areas provide cover and concealment for organized positions, shelter for reserve formations, and an obstacle to the attacking forces. Usually the defender is able to make a detailed reconnaissance of the area, so that he is familiar with the roads, trails, and other features of the terrain. Infantry weapons form the basis of the defense, due to the difficulty of securing observed artillery fire in heavily wooded areas.

f. Construction.

- (1) The usefulness of trees for timber is determined by their height and diameter, and by the nature of the wood as hard, soft, or fibrous. Deciduous trees generally are hardwoods.

Needleleaf trees are softwoods that usually are easily worked, although some species are fibrous and difficult to saw.

- (2) When a forest area must be cleared of trees prior to a construction project, a study of the ground will indicate the density and depth of the root systems. Where a forest is closely underlain by hardpan or rock, tree roots branch and remain near the surface, making them easy to uproot. In soil that is firm, with deep underlying rock, trees tend to form large taproots extending to a considerable depth, making them difficult to remove. Trees in inundated, marshy, and muskeg areas have thick widespreading and shallow root systems near the surface of the ground. In northern regions where permafrost occurs, its effect on the root systems of trees is similar to that of hardpan or rock. Where the permafrost is near the surface, the roots branch and lie close to the surface. Deeper taproots are developed where the permafrost is far below the surface.

100. Information Requirements

As far as practicable, information about the vegetation in an area is presented in the form of a map overlay that clearly indicates and identifies the major vegetation types by the use of color and symbols. The accompanying text briefly summarizes the additional information of military significance that cannot be shown adequately on the map. Pertinent information may include the following:

a. Forests.

- (1) Name or other identification.
- (2) Plant associations.
 - (a) Principal species (names, proportion in percent, density or average spacing, height range).
 - (b) Undergrowth species.
- (3) Canopy: structure (continuous, open, broken) and seasonality (color, defoliation).
- (4) Duff (partly decayed vegetable matter on the forest floor): abundance and nature of fallen trees, logs, and so on.
- (5) Exploitation practices (normal cutting, overcutting, under-cutting).
- (6) Operational aspects (suitability for cover, concealment, blowdown susceptibility, camouflage, and fuel).
- (7) Principal tree species.
 - (a) Name (English and botanical).
 - (b) Height (average).
 - (c) Growth form (triangular, linear, and ovate).
 - (d) Diameter (average).

- (e) Leaves (broadleaf or needleleaf).
- (f) Period of defoliation.
- (g) Roots (structure, size, toughness).
- (h) Suitability for construction.
- (i) Special features (toxicity, thorniness, edibility).
- (j) Indicator significance (relation to regional and local climates, kind and state of ground, and ground water, salinity, permafrost, depth and duration of snow cover, human activity).

b. *Shrubs*.

(1) *General*.

- (a) Location and areal extent.
- (b) Name or other identification.
- (c) Principal species (names, proportion in percent, density or average spacing, height range).
- (d) Foliage—density and seasonality (color, defoliation).
- (e) Operational aspects (susceptability to mass conflagration).

(2) *Principal shrub species (for each)*.

- (a) Name (English and botanical).
- (b) Height (average).
- (c) Growth form.
- (d) Diameter (average).
- (e) Leaves.
- (f) Period of defoliation.
- (g) Roots (structure, size, toughness).
- (h) Special factors (toxicity, irritancy, thorniness, edibility).
- (i) Indicator significance (kind and state of ground).

c. *Grasses*.

(1) *General*.

- (a) Location and areal extent.
- (b) Name or other identification.
- (c) Principal species (names, proportion in percent, density, height range).
- (d) Seasonality (dates of growth, color).
- (e) Operational aspects (susceptability to mass conflagration).

(2) *Principal species (for each)*.

- (a) Name (English and botanical).
- (b) Date of maturity, height.
- (c) Life span.
- (d) Growth habit (sod or bunch).
- (e) Suitability as forage.
- (f) Special factors (toxicity, irritancy).
- (g) Indicator significance.

d. Cultivated Crops.

(1) *General.*

- (a) Location and areal extent.
- (b) Name or other identification.
- (c) Principal crops (names, proportion in percent, density or spacing height range; if applicable, months planted, cultivated, and harvested; crop rotation practices).
- (d) Canopy, foliage, or stand (as applicable: structure, color, defoliation, density, rates of growth).
- (e) Types of farming (irrigated, dry, and so on).
- (f) Special factors associated with crops (irrigation ditches, flooding, terraces, hedgerows, dikes, and stone or other types of fences).
- (g) Operational aspects (susceptability to mass conflagration).

(2) *Principal crops.*

- (a) Tree and shrub crops (same information as for tree species; in addition, months that the crops are harvested).
- (b) Grass and grain crops (same information as for tree species; in addition, months of planting and harvesting).

CHAPTER 7

MANMADE TERRAIN FEATURES

Section I. GENERAL

101. Definition

Manmade features include all the changes in the natural environment made by man in the course of living on the earth and using its resources. Major manmade features are cities, defensive works, transportation and communication facilities, and similar features that have significant effects upon military operations. Others are such features as cemeteries, hedgerows, and buildings, which affect only local operations.

102. Significance

In preparing terrain studies, manmade features must be evaluated to determine their effect upon the military aspects of proposed operations. Recommendations may be made to destroy certain features or to retain them for future use after the operation has been completed. Usually each major manmade feature is the subject of a detailed study by military intelligence personnel.

Section II. ROUTES OF COMMUNICATION

103. General

a. The routes of communication of an area consist of all the roads, railways, and waterways over which troops or supplies can be moved. The importance of particular features will depend upon the level of the unit and the type of operations being conducted.

b. The ability of an army to advance and to carry out its mission depends greatly upon its routes of communication. One of the primary considerations in planning is the extent and general nature of the transportation network. This is particularly true in large-scale operations. Planners must consider the advantages and disadvantages of the entire pattern of transportation facilities. An area with a dense transportation network, for example, is favorable for major offensives. One that is crisscrossed with canals and railroads, but possesses few roads, will limit the use of wheeled vehicles and the maneuver of armor and motorized infantry. Railroads extending along the axis of advance will assume greater importance than those perpendicular to the axis, and the direction of major highways and waterways assumes equal significance.

104. Roads

a. Definition. The term roads includes all types of roads and tracks, from multilane superhighways to minor pack trails and footpaths. Bridges, ferries, snowsheds, and similar structures and facilities that provide continuity of movement and protection for the way are also considered as integral parts of the road system.

b. Requirements.

- (1) An adequate road system is a fundamental requirement in the conduct of any major military operation. Terrain studies must provide information about the roads which exist in the area under consideration and should indicate where new roads will be needed to support a proposed operation.
- (2) Roads in the combat zone usually need meet only minimum standards, but those in rear areas, especially in the vicinity of water terminals, airfields, and supply installations, must be well-surfaced and capable of carrying heavy vehicle traffic without excessive maintenance. Operations on a wide front and the employment of nuclear weapons will require a large number of secondary roads in both forward and rear areas.
- (3) The information presented in a terrain study should indicate the minimum maintenance and construction requirements that may be anticipated during a planned operation. Continual maintenance of a road net is essential. In addition to the severe punishment given to roads by large volumes of heavy traffic, important bridges, intersections, and narrow defiles are primary targets for enemy bombardment. The maintenance of unnecessary roads must be avoided, and the construction of new roads held to a minimum.

c. Classification. Roads usually are classified as follows:

- (1) *All-weather road.* Any road which with reasonable maintenance is passable throughout the year to a volume of traffic never appreciably less than its maximum dry-weather capacity. This type of road has a waterproof surface and is only slightly affected by rain, frost, thaw, or heat. At no time is it closed to traffic by weather effects other than snow blockage. In this category are roads paved with concrete, bituminous surfacing, brick, or stone.
- (2) *Limited all-weather road.* Any road which with reasonable maintenance can be kept open in bad weather to a volume of traffic which is considerably less than its maximum dry-weather capacity. This type of road does not have a waterproof surface and is considerably affected by rain, frost, or thaw. Traffic is halted completely for short periods of a day or so at a time. Heavy use during adverse weather

conditions may lead to complete collapse of the road. Crushed rock or waterbound macadam, gravel, or a lightly metalled surface are typical of roads in this category.

- (3) *Fair-weather road.* A road which quickly becomes impassable in bad weather and which cannot be kept open by normal maintenance. This type of road is so seriously affected by rain, frost, or thaw that traffic is brought to a complete halt for long periods. In this category are roads of natural or stabilized soil, sand-clay, shell, cinders, and disintegrated granite.

d. Classification by Location and Use. Military roads are classified as follows:

- (1) *Axial road.* A road leading toward the front and generally perpendicular thereto. When designed as the principal traffic artery of a division or higher unit, such a road is termed a main supply road (MSR).
- (2) *Belt road or lateral road.* A road generally parallel to the front.
- (3) *Reserved road.* A road reserved by competent authority for designated traffic.
- (4) *Restricted road.* A road on which traffic is controlled as to character, speeds, loads, or time of use.

e. Classification of Civilian Roads. Civilian roads are classified as—

- (1) *Main roads.* These are roads which serve as the principal thoroughfares between the important populated places of an area.
- (2) *Secondary roads.* Roads in this classification connect the cities and towns of an area. In this category is any road which connects two main roads, at least one of which is in a higher classification than the connecting road. They have a less substantial construction than main roads and commonly do not carry as heavy a volume of traffic.

f. Classification of Foreign Roads. On maps of foreign areas prepared or edited for use by friendly forces, the following road classifications apply:

- (1) *Hard-surface, all-weather roads.* Roads in this category will carry fairly heavy truck loads in all weather. Minimum maintenance requirements are periodical inspection and repair. Construction is usually concrete or asphaltic concrete, bituminous macadam, surface-treated oiled gravel, or light tarbound macadam.
- (2) *Loose-surface, graded, all-weather roads.* The roads will carry light loads in all weather and generally are drained and graded. Periodic maintenance is required. Construction

usually is of gravel, stone, or some stable material such as sand-clay on a light foundation.

- (3) *Loose-surface, dry-weather, or dirt roads.* Roads of this type will carry light loads in dry weather only. They may or may not be graded and will require continual maintenance. Any surfacing consists only of gravel or sand-clay, with a poor foundation.
- (4) *Tracks.* This category includes winter roads, caravan routes, and natural roadways. Usually they will accommodate very light vehicles, such as $\frac{1}{4}$ -ton trucks, in dry weather. Tracks normally are shown only on maps of areas that have a poor road system.

g. Military Considerations. Road studies must include an evaluation of the problems that may arise because of adverse terrain, weather and climate, poor original design and construction, and inadequate maintenance.

- (1) *Adverse terrain.* Swamps, bogs, and lowlands such as delta areas may create special problems of drainage and ditching, necessitate measures to give added support to the roadbed, and require the construction of many bridges. Rugged topography may result in steep grades and sharp curves, tunneling, bridging, cuts, and sidehill locations in laying out new roads. Sidehill locations, in turn, may require retaining walls, cribbing, and snowsheds to give protection against earth, rock, or snow slides. In the desert, sand fences, and special crews and equipment to keep the roads clear of drifting sand may be required. Arctic terrain requires special techniques to build and maintain roads on permafrost and periodically frozen ground.
- (2) *Weather and climate.* Sustained periods of freezing, heavy snowfalls, and similar extreme weather conditions may seriously affect the use, maintenance, and construction of roads. Protection must be provided against snow drifts, and there must be provisions to remove the snow and to repair damage due to frost heave and frost boils. Excessive rainfall may result in washouts and flooding in low areas and cause earth and rock slides in rugged terrain. Continuous wet weather may make unsurfaced roads impassable. In dry periods, dust control becomes an important factor wherever unsurfaced roads are used to any great extent.
- (3) *Poor original design and construction.* Terrain studies should include an engineering evaluation of the structural soundness of all roads in an area under consideration. If the initial design did not provide for the increased loads and speeds that would accompany military use or if the road

was improperly constructed originally, it may prove a serious obstacle to movement. Repairs and excessive maintenance may be required because of an unstable subgrade; inadequate drainage of the subgrade, surface, or slopes; sharp curves, and loose or unsealed wearing surfaces that result in saturated roadbeds.

- (4) *Lack of regular maintenance.* Poor maintenance of a road is shown by clogged culverts and ditches; potholed, bumpy, and rutted surfaces; soft and uneven shoulders, and badly worn and cracked pavements. Studies should indicate where these conditions exist and the maintenance that would be required to bring the roads up to minimum military standards.

h. Information Requirements. Information about roads is recorded on map overlays that show the alinement of the significant roads, with the location of associated bridges, tunnels, ferries, fords, and critical points such as rock-slide areas. Ordinarily the local system of route numbers is used. If no system exists that is satisfactory for terrain intelligence purposes, an arbitrary system is established to identify the main and secondary roads. Information about individual roads usually includes the following:

- (1) Name and route number.
- (2) Terminal points; intermediate localities on the road; distances between major points.
- (3) Terrain (elevations, irregularities, slopes, drainage, soils).
- (4) Length.
- (5) General condition (necessary repairs and improvements, with nature and location).
- (6) Surface material (by sections, if there are changes in type of surface along the route).
- (7) Ratings of alinement, drainage, foundation, and surface.
- (8) Roadbed (width of traveled way; type and width of shoulders).
- (9) Maximum grade.
- (10) Sharpest curvature.
- (11) Significant cuts and fills.
- (12) Clearance (minimum vertical and horizontal clearances, with nature of restrictions).
- (13) Bridges (load capacity, general condition).
- (14) Tunnels (length, width, clearances, condition).
- (15) Fords and ferries (type, general characteristics, condition).
- (16) Critical points; location and characteristics of possible by-pass routes or detours around bottlenecks.
- (17) Location and characteristics of routes that provide maximum protection from ground or air attacks.

- (18) Snow removal (northern and mountainous areas).
 - (a) Critical areas (location, dimensions).
 - (b) Periods when snow fencing is required; locations.
 - (c) Available snow-removal equipment.

105. Bridges

a. General. Road and railway bridges are vulnerable points on a line of communication. Timely preservation, destruction, or repair of a bridge may be the key to an effective defense or to successful penetration of an enemy area. A bridge seized intact has great value in offensive operations, since even a small bridge facilitates the movement of combat troops across a river or stream. Information about bridge types and their classification is contained in TM 5-260 and FM 5-36.

b. Bridge Sites. Because of the time and labor involved, new bridges are erected only when an existing bridge, ford, or detour cannot be used. Terrain suitable for a bridge site should meet the following requirements:

- (1) Satisfactory river conditions, with no fast currents or great depths.
- (2) Site readily accessible from the road it serves.
- (3) Firm, well-drained approaches, preferably above flood level.
- (4) For floating bridges, a riverbed free from snags, rocks, and shoals and firm enough to hold anchors and to support trestles.
- (5) Firm, stable banks of suitable height. (High banks require excessive grading to prepare the approaches. Low banks may be subject to a rising river level that will flood the bridge site.)
- (6) Adequate, well-drained working areas close to the site including a bivouac for the working party, space for construction materials, and turnarounds and parking places for vehicles and heavy mobile equipment.
- (7) Areas close to the site, near or alongside the approach roads, where vehicles can park off the road and under cover while awaiting their turn to cross.

c. Information Requirements. Detailed information about bridges cannot be obtained from topographic maps, but indications on air photographs usually will permit an approximate determination of the width, clearance, and height above water of a bridge. Details such as the condition, capacity, and structure of a bridge should be obtained by engineer reconnaissance. Reconnaissance procedures are described in TM 5-260 and FM 5-36. Basic information requirements for a bridge should include a summary of its structural characteristics, its critical dimensions (length, usable width, overhead clearance) an

estimate of capacity, and general condition. Detailed information includes the following :

- (1) Type; number of lanes and width of each; number of spans and length of each; length of panels; arrangement of spans.
- (2) Height above riverbed; overhead clearance for vehicles; class.
- (3) Stream data: width, depth, velocity of current; direction of flow; type of bottom; estimated bearing capacity of bottom; height, slope, and nature of banks.
- (4) Description, dimensions, and condition of access roads and approaches.
- (5) Type, dimension, and condition of abutments, stringers, flooring, girders, and other structural elements.
- (6) If damaged or wrecked—
 - (a) Structural details of bridge in its original form.
 - (b) Nature and extent of damage; position of debris; details regarding any salvageable materials.
 - (c) What loads, if any, can still cross the bridge.
 - (d) If not suitable for use, information about alternate sites.

106. Railways

a. General. The term *railway* includes all fixed property belonging to a line, such as land, permanent way, bridges, tunnels and other structures. Railways assume increased military importance in areas where the soils are generally untrafficable, roads are poor, and rail transportation facilities are extensive. Frequently, railways can be used as substitute roads for vehicles. Railway bridges will carry tanks without reinforcement.

b. General Characteristics.

- (1) The basic elements of a railroad include rolling stock; track-age; yards, terminals, regulating stations, and railheads; transshipment points; water and fuel stations; and signal communication facilities.
- (2) A *yard* is an area containing a system of interconnected tracks and is used for making up trains, storing cars, and general maintenance activities.
- (3) A *railhead* is the point at which supplies destined for a particular unit, installation, or area are transferred from rail to another type of transportation, usually trucks.
- (4) A *regulating station* is an installation on a military railway line at which the movement of supplies and personnel is controlled. Its facilities include a yard, open and covered storage, and usually, temporary housing and messing facilities for transient personnel.

c. *Military Considerations.*

- (1) The development and extent of a railway system largely reflect the topography of the region that it traverses. In desert regions, for example, a single railroad may extend in a straight line across vast barren wastes. A long, narrow country such as Chile may have only short transverse railroad lines extending inland from the ocean, which provides the main communication route. In hill regions and mountain areas, the railways run through valleys, with short lines leading off into the more rugged terrain. On plains, railways will have few curves but may be subject to the effects of poor drainage conditions. Generally, railways tend to follow rivers because of the more uniform grades, the availability of straight routes, and the concentration of resources, industries, and population centers along the waterway. The terrain characteristics of an area can be determined to a considerable degree by a study of the railway routes, since the rail lines almost invariably follow the topography that offers the fewest obstacles.
- (2) Railways are essential for extended military operations. Their capabilities are of primary concern and are the subject of continuing studies by personnel at the highest levels. Detailed intelligence about the railways in an area of operations is produced by technical specialists of the Transportation Corps and the Corps of Engineers.
- (3) Railways are highly vulnerable to enemy attack, particularly to sabotage and guerrilla operations. Keeping a railroad line in operation requires trained security forces and extensive protective measures. Often these represent such a drain upon the available manpower that railways in an active theater may be used only to a limited extent in forward areas.

d. *Evaluation of Railways.* In evaluating a railway for terrain intelligence purposes, consideration should be given to the effects of adverse terrain, weather and climate, and the overall design and construction of the system. The following factors should be considered:

- (1) *Adverse terrain.* Railways passing over swamps, bogs, and delta terrain may encounter special problems of drainage, ditching, and roadbed maintenance. In mountainous areas, steep grades, sharp curves, and tunnels are common. Because of sidehill locations and deep cuts, there should be protection against earth, rock, and snow slides. In the desert, drifting sand is a problem and provisions should be made to remove it.
- (2) *Adverse weather and climate.* Severe winter conditions seriously retard operation and maintenance of railways,

requiring protection against drifting snow, provisions for snow removal, and repairs because of damage caused by frost heave. Excessive rainfall may result in washouts and flooding in low areas and cause earth and rock slides in rugged terrain.

- (3) *Overall design and construction.* A railway may prove inadequate because the initial design did not provide for the increased loads and speeds or heavier volume of traffic needed. As a result, a railway might require either considerable reconstruction and repair or excessive maintenance. Among the more common defects of this character are an unstable subgrade, lack of adequate drainage, light rail, poor ballast, and untreated ties. Improper maintenance may also cause difficulties. This is evidenced by such conditions as an uneven roadbed, improperly tamped ties, loose fastenings, badly worn rail or uncleared drains. Terrain studies should evaluate the condition of a railway in considering its suitability for use in operation.

e. Information Requirements. Railway information should be recorded on a map or overlay that shows the true alinement of all rail lines; their trackage, gage, and status; and the location of all bridges, tunnels, and ferries. The existing system of line numbers is used or, if that is not satisfactory, a suitable arbitrary system is adopted. Fundamental information about railways should include the following:

- (1) *Railway network.*
 - (a) Total mileage.
 - (b) Location and details of main lines.
 - (c) Gage; changes in gage on routes.
 - (d) Number of tracks.
 - (e) Ruling grades and curves.
 - (f) Location and length of passing tracks.
 - (g) Type and weight of rail.
 - (h) Permissible loads; capacity of bridges.
 - (i) Yards and terminals (location, type, capacity).
 - (j) Details of servicing facilities and other installations.
 - (k) Operating factors—
 1. Number of cars per train, passenger and freight.
 2. Average speed of passenger and freight trains.
 3. Number of trains each way per day.
 - (l) Bridges and tunnels (location, description).
 - (m) Rail ferries (location, type, capacity).
 - (n) Electrification (location, type).
 - (o) Transshipment points.

(2) *Individual rail line.*

- (a) Name.
- (b) Terminals, intermediate stations, length of each stretch.
- (c) Obstructions (demolitions, washouts, blocked tunnels).
- (d) Gage.
- (e) Number of tracks.
- (f) Weight of rails.
- (g) Grades and curvatures.
- (h) Ties, ballast, roadbed.
- (i) Sidings and passing tracks (location, lengths, switches).
- (j) Tunnels (locations, clearances).
- (k) Overhead structures and vertical clearances.
- (l) Drainage facilities, including culverts.
- (m) Bridge data.
- (n) Operating and repair facilities (loading and unloading; fueling, watering, icing; stocks of fuel on hand; yards; administrative and servicing facilities; signal, traffic-control, dispatching facilities).
- (o) Rolling stock.
- (p) Availability of trained and dependable personnel.
- (q) Transshipment points.

(3) *Equipment.*

- (a) Present condition, and interchangeability with equipment of other countries.
- (b) Motive power (type, size, weight, tractive effort, wheel arrangement, type and height of couplings).
- (c) Rolling stock (type, number, car dimensions, capacity, weight).
- (d) Rail cars (type, size, capacity).
- (e) Work cranes (type, size, capacity).
- (f) Snow plows (type, size).
- (g) Armored equipment (type, size).
- (h) Repair shops (location, size).

107. Inland Waterways

a. Definition. The term inland waterway is applied to those rivers, canals, lakes, and inland seas of a country which are used as avenues of transport (fig. 54). It includes all the fixed property which affects the movement of vessels carrying passengers or freight. Types of inland waterways include—

- (1) Inland lakes and land-locked seas.
- (2) Rivers.
- (3) Ship canals.
- (4) Barge canals.



Figure 54. Inland waterway through a marsh (Utah).

- (5) Intracoastal waterways (waterways usually running parallel to the coastline of a land mass and sheltered enough to permit the navigation of small vessels).

b. *Classification.* Inland waterways can be classified according to their depths as follows:

- (1) *Very shallow.* Depths less than $4\frac{1}{2}$ feet.
- (2) *Medium.* Depths between $4\frac{1}{2}$ and 7 feet.
- (3) *Deep.* Depths greater than 7 feet.

c. *Military Considerations.*

- (1) *Advantages.* Inland waterways provide an economical form of transportation for bulk supplies, freeing faster modes for shipments of a higher priority. Frequently, large or very heavy items that cannot be handled by truck and rail can be shipped by waterway. One of the major uses of waterways in an active theater is the transportation of supplies for the rehabilitation of the economy in liberated areas, thus reducing the demands upon military transportation facilities.
- (2) *Limitations.*
 - (a) Waterways are vulnerable to extremes of weather and climate. Unless icebreaking operations can be conducted, traffic is halted completely during a freezing period. The thaw following a freezeup may cause floods, and periods of drought may result in insufficient water for the movement of vessels.
 - (b) The locks, bridges, cuts, dams, and other facilities associated with waterways are vulnerable to enemy action. Withdrawing enemy troops usually blocks the waterway system by dropping rail or road bridges into the waterway; damaging locks and levees, obstructing channels with ships and barges; draining canals, and destroying, dismantling, or moving essential equipment.

- (c) Waterway transport is slow compared with other modes. It is also inflexible, since new waterways cannot be constructed during military operations.
- (d) The depths of rivers and streams used as waterways fluctuate with the seasons of maximum and minimum rainfall. Streams with fairly direct courses commonly are interrupted by falls and rapids. Streams of low and uniform gradients usually meander, resulting in long and indirect routes of transport. Their channels shift constantly, depositing sandbars, which are a menace to navigation.

d. Information Requirements. Inland waterway information should be recorded on a map or overlay that shows the true alinement of the navigable waterways, the location of all locks, dams, aqueduct bridges, tunnels, and major landing facilities, and the location of specific structures which limit the vertical and horizontal clearances on each navigable reach. The local names are used to identify waterways and structures whenever feasible. Detailed information requirements should include the following:

(1) *Developed waterways.*

- (a) Geographical location (name, origin, terminus, length).
- (b) Restricting widths and depths of channel.
- (c) Frequency, duration, and effects of seasonal changes (floods, low water, droughts, excessive currents, normal freezeup and opening dates).
- (d) Location, description, and restrictive effects of structures (locks, safety gates, dams, bridges, ferry crossings, aqueducts, tunnels, cable crossings).
- (e) Speed and fluctuation of current.
- (f) Location and capacity of terminals and repair facilities.
- (g) Maintenance requirements.
- (h) Craft (number, type, capabilities).
- (i) Communication facilities.
- (j) Availability of civilian personnel.

(2) *Navigable rivers.* In addition to the items listed in (1) above, the following additional information may be required:

- (a) Physical characteristics of the river (bottom, banks, feed-water streams, and important tributaries).
- (b) Navigational hazards, such as falls, rapids, and sandbars.
- (c) Navigational aids, location, and type (buoys, lights, range markers, radar, foghorns).
- (d) Changes in channel.
- (e) Dredging requirements.

Section III. PETROLEUM AND NATURAL GAS INSTALLATIONS

108. General

a. The major oil fields occur along the foot of the great mountain chains or in adjacent lowlands that contain sedimentary rocks. Often petroleum, gas, and water are found together.

b. Natural gas occurs both alone and with petroleum. Gas from oil wells is known as *wet* gas and is rich in volatile gasoline. It is drawn from the well and run to a plant where the gasoline is extracted. Wells which produce only gas are known as *dry* wells and feed the gas directly into pipelines for distribution.

109. Characteristic Installations

a. Regardless of the methods employed, a well requires a derrick to support the drilling equipment (figs. 55 and 56). These derricks are usually the distinguishing characteristics of an oil or gas field.

b. A bulk distribution system for petroleum products may include ship-to-shore and dockside loading and unloading facilities, bulk storage tank farms, pipelines, pumping stations, bulk delivery points or pipeheads, and testing laboratories.

c. Military pipelines are used to transport liquid fuels, chiefly jet fuel and gasoline. Occasionally they are also utilized to transport diesel fuel and kerosene. Usually 6-inch pipe is used, with 8-inch pipe employed for ship unloading or truck lines. The pipeline follows the most direct level route, within 20 or 30 feet of all-weather roads so as to facilitate construction, patrol, repair, and security of the line. Cross-country lines are used if a road winds excessively. Normally a line is diverted around difficult terrain such as marshes, swamps, or land that is subject to periodic flooding. It also avoids thickly populated areas and military installations that have a high element of hazard, such as ammunition dumps.

d. A *tank farm* is a group of storage tanks connected to pipelines through an assembly of pipes called a *manifold* which permit the movement of petroleum products into, out of, and between the tanks. A farm may include *dispensing tankage* for the issue of fuels and *regulating tankage* located along the pipeline to control the flow. *Throughput* is the capacity of the pipeline to transport a quantity of fuel per unit of time, usually expressed in the number of 42-gallon barrels per hour or in gallons per minute. Tank farms may vary in size from a pair of regulating points sited along the pipeline to a major storage complex consisting of a number of separate farms with a storage capacity of a million barrels or more. Because of their vulnerability to air attack, and to nuclear attack by either air or missile delivery systems, military tank farms are limited to a total capacity of no more than 250,000 barrels. The storage tanks are made of steel



Figure 55. Oil field.

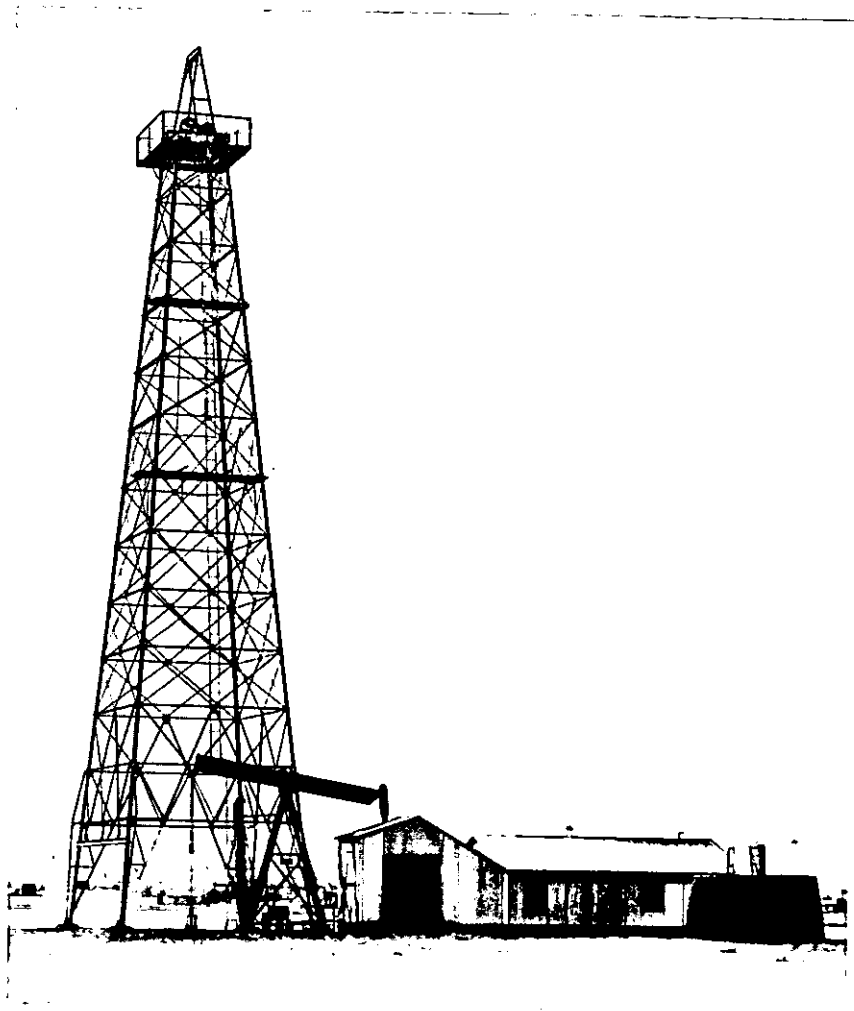


Figure 56. Typical oil well installation (Kansas).

or aluminum with various capacities up to 10,000 barrels. Portable fabric tanks also are used in military operations at forward supply points and at beachheads.

e. Base terminals normally are located in rear areas, at or near theater ports of embarkation or other tanker unloading points. *Pipehead terminals* are located at the forward end of a military pipeline, moving forward with the army supply point to support the advancing forces.

110. Military Considerations

a. The petroleum and natural gas resources of a country or region are fundamental to its economy and its military capabilities. Ac-

cordingly, the gas and oil wells, distribution systems, and storage installations are primary targets for air attack and are major objectives. They may form the principal objective of a campaign initiated to seize them for our use or to deny their advantages to the enemy.

b. Base terminals are prime targets for enemy air attack, including attack by nuclear weapons and guided missiles. Normally, alternate and duplicate facilities are provided for major storage and vessel-unloading installations. These are sited, after an evaluation of the terrain, at locations far enough apart so that more than one installation will not be destroyed or damaged by a single nuclear explosion.

111. Information Requirements

The location and extent of petroleum and gas facilities should be recorded on a topographic map of suitable scale. A numbering system is established to identify petroleum pipelines, gas pipelines, producing fields, plants, and storage facilities. A separate series of numbers is used for each pipeline. Such pipeline facilities as pumping stations and tank farms are numbered serially, beginning from a designated initial point on the line. Local names may be used for individual installations. Basic information requirements should include the following:

a. General.

- (1) Location and type of raw material (oil, oil shale, natural gas); character of crude oil.
- (2) Reserves of raw material (in million barrels, tons, million cubic feet).
- (3) Refineries (location, nature of product, quality of product, daily capacity, type of installation, and details of construction).
- (4) Storage.
 - (a) Location, nature, capacity, present contents of tank farms, individual tanks, other forms of storage, including amounts presently in pipelines.
 - (b) Stocks (location and type).
 - (c) Pipelines and distributing systems.

b. Pipelines.

- (1) Name, if any; location of lines; material transported.
- (2) Terminals.
- (3) Number and diameter of pipes; delivery capacity of system at present and under normal conditions; content of pipeline when full.
- (4) Facilities at base terminal (if a water terminal, method of loading from tankers).
- (5) Storage facilities at terminals and along pipelines, with capacity of each installation.
- (6) Pumping stations (location, capacity, equipment).

- (7) Administrative, maintenance, and repair facilities.
- (8) Security and safety provisions.
- (9) Physical condition of installations and equipment; required major repairs or improvements.
- (10) Availability of trained and reliable personnel.

Section IV. MINES, QUARRIES, AND PITS

112. Mines

a. General. The important mineral resources of a country or area include metallic ores such as iron, copper, zinc, lead, tin, silver, gold, and uranium; mineral deposits, principally sulphur, phosphate rock, gypsum, graphite, asbestos, and bauxite; and solid fuels, chiefly coal, lignite, and peat. Terrain studies list each significant mineral, covering in detail the estimated quantities available and the methods and facilities employed to mine, process, and distribute each type of mineral.

b. Mining Operations.

- (1) Mineral deposits are exploited either from the surface of the ground or from underground shafts and tunnels, the method depending upon the depth of the deposit below the surface.
- (2) A typical underground mine consists of a vertical *shaft*, horizontal passages opening out of the shaft, and vertical passages driven from above (*winzes*) connecting the levels. Openings branching off from the levels, where the ore is actually extracted, are called *stopes*. Supports in mine working usually are made of timber treated with preservatives or of reinforced concrete, steel, brick, or stone. Pillars of ore may be left as supports, finally being mined when the workings are vacated.
- (3) Where ore beds lie close to the surface, the mineral may be removed from open pits after stripping off the overlying earth and rock. This is *strip* mining, the coal or other mineral being removed by power shovels.
- (4) *Placer* mining involves the removal of overburden by hand, hydraulic nozzles or dredges, and subsequent separation of the ore from waste by panning and sluicing. It is widely employed to mine gold.
- (5) In *open-pit* mining, an excavation is made. In the case of deep pits, the sides usually are cut into steps or benches. Access to the below-ground-level site may be obtained by arranging these benches in spiral form, by cutting inclined approaches, or by sinking a shaft connected to the mine by an *adit* or tunnel (fig. 57).



Figure 57. Open-pit copper mine.

- (6) In *glory-hole* mining, the excavation is funnel-shaped, and a vertical passage (*raise*) driven from below connects with an underground haulage level. The ore slides down this passage into the haulage level for removal.

c. *Military Considerations.*

- (1) To a great extent, the ability of any nation to support a war depends upon its mineral resources. Enemy mines are accordingly a major objective and priority targets for air attack. The seizure or defense of important mines may also be the mission of troop units of any size.
- (2) Mines provide concealment and cover, but their use as shelter for troops may be hazardous and is seldom practicable. Most mines will not withstand the effects of heavy surface bombardment. Coal mines are especially unsuitable for troops or storage. Coal is structurally unstable and requires extensive supports even in ordinary mining operations. Many varieties of coal give off a gas known as *fire damp* or *marsh gas*. This is highly flammable and highly explosive when mixed with air. Coal dust and air also form an explosive mixture.
- (3) Some mines, particularly salt mines, may be utilized for the storage of supplies and equipment. Adit mines, with horizontal or slightly inclined entries, are more suitable than verticle-shaft mines for underground storage. The latter type may present drainage problems and offers more difficulties in transporting loads in and out of the mine.
- (4) To prevent their use by the enemy, mines can be flooded or destroyed with explosives. The possibility of mines being used as headquarters for guerrillas must be considered, and inactive mines in a tactical area should be blocked, destroyed, or otherwise secured against occupancy by hostile elements.

d. *Information Requirements.* The information about a mine required for a terrain study will depend upon the purpose of the study. Such information as the following usually is required :

- (1) *Location and name of mine.*
- (2) *Product.*
 - (a) Mineral extracted.
 - (b) Quality (raw material, partly refined, fully refined).
 - (c) Quantity produced in a normal operating year and under present conditions.
 - (d) Estimated reserves underground.
- (3) *Extraction methods.*
 - (a) Deep mining of solid ore.
 - (b) Placer mining.

- (c) Shallow or strip mining.
- (d) Special methods (sulphur, salt, and so on).
- (4) *Details of layout and operation.*
 - (a) Pits, shafts, galleries, wells.
 - (b) Hand and mechanical labor involved.
 - (c) Aboveground structures, plant and equipment.
 - (d) Refining processes.
 - (e) Storage facilities.
 - (f) Transportation facilities.
 - (g) Utilities (ventilation, electric power, lighting, water, fire-fighting).
- (5) *Physical condition of installations and equipment.*
- (6) *Safety and security features.*
- (7) *Availability of labor.*
- (8) *Any major repairs needed for operation.*

113. Quarries and Pits

a. Quarries.

- (1) A quarry is a site providing rock that is suitable in quality, quantity, and size for construction purposes. A *hard-rock* quarry furnishes rock such as granite, limestone, or sandstone, which must be drilled and blasted in quarrying and which must be crushed for some uses. A *soft-rock quarry* furnishes material that can be removed readily by earth-moving equipment. Soft coral, caliche, shale, chalk, and tuff are materials of this type.
- (2) Quarries are generally the open-faced type, with the vertical surface of the rock exposed. Depending upon local conditions, they may be developed by the single or multiple bench method. A single-bench quarry has the entire floor on one level, the height of the bench worked in one operation varying from 8 to 100 feet. A multiple-bench quarry is one having a series of ledges or terraces resembling steps.

b. Pits.

- (1) A *pit* is a site where earth or rock particles suitable for engineer construction may be obtained in quantity. A *borrow pit* is a site providing soil suitable for fills, surfacing, or blending that can be removed with earth-moving equipment.
- (2) A *gravel pit* consists predominantly of particles of gravel size. Unsorted gravel from pits is used extensively for surfacing secondary roads, in base courses for pavements for roads, taxiways, and runways, and as aggregate in concrete and bituminous operations. An *alluvial gravel pit* derives its name from the origin of the deposit, since the material is stream-deposited. The gravel obtained from these pits

usually is very clean and free from clay and humus. It is therefore particularly desirable for concrete and bituminous work. A *bank* or *hill* gravel pit produces a clayey gravel or clayey sandy gravel. These materials are very desirable for surfacing work because of their binding qualities.

c. Military Considerations.

- (1) Pits and quarries are important chiefly as sources of materials for engineering construction. They may be local objectives in tactical operations, if plans require extensive engineering development of the area.
- (2) Individual pits and quarries usually can be bypassed by advancing forces, but an area containing a number of them may present difficulties to the movement of larger units and will tend to canalize movements. Flooded quarries are a particularly hazardous obstacle.
- (3) Pits and quarries provide a varying degree of cover for troops. They may also furnish defiladed locations for artillery and missile positions.

d. Information Requirements.

(1) *Quarries.*

- (a) Location.
- (b) Nature of stone.
- (c) Actual and potential capacity in uncrushed stone.
- (d) Capacity of crushing machinery in stone of various sizes.
- (e) Details of machinery.
- (f) Loading facilities.
- (g) Amount of crushed stone that can be hauled away in a day, considering the manner of loading, number of trucks that can be loaded at one time, access road, and turnarounds.

(2) *Pits.*

- (a) Location.
- (b) Nature of source.
- (c) Nature of raw materials; quality, quantity.
- (d) Amount, depth, and type of overburden.
- (e) Drainage; ground-water level; standing water.
- (f) Utilities available (electricity, water).
- (g) Equipment available.
- (h) Method of extraction (hand labor, machinery, dredging).
- (i) Method of cleaning and sorting.
- (j) Daily production capacity.
- (k) Transportation routes; access roads; surfaces of roads.

Section V. AIRFIELDS

114. General

a. Airfields range in size and function from short landing strips consisting of little more than a cleared area suitable for light liaison planes or helicopters to large permanent air bases with many complex supporting installations (fig. 58). The various types are discussed in TM 5-250.

b. The simplest form of operational airfield consists essentially of a runway, usually oriented in the direction of prevailing winds; one or more perimeter taxiways, with warmup aprons located where they join the ends of the runway; and hardstands to accommodate one or more groups of aircraft. The runway may or may not be surfaced. In addition, there will be a minimum of other facilities, such as access and service roads, fuel storage, ordnance storage, and a control tower. The particular characteristics will depend upon the type of aircraft that will use the field.

c. A tactical airfield in a theater of operations includes the following major elements:

- (1) Landing strips.
- (2) A system of hardstands and runways.
- (3) Warmup aprons close to one or both ends of the runway.
- (4) Operation facilities, including control tower and operations and briefing rooms.
- (5) Fuel storage facilities.
- (6) Ammunition storage facilities.
- (7) General supply storage facilities.
- (8) Repair and maintenance facilities for aircraft, accessories, and automotive vehicles.
- (9) Roads, walkways, communications, fire-fighting unit, and other service facilities.
- (10) Security and safety installations.

115. Terrain Requirements

The general location of a proposed airfield is indicated by the air force commander or the Army aviation officer, as appropriate, while the exact site is chosen by the engineer after a careful evaluation of the terrain. In selecting a site, the following factors should be considered:

- a.* Adequate dimensions to meet operational requirements, with room for future expansion.
- b.* Accessibility to supply routes and communication facilities.
- c.* Obstructions along flightways and approaches, including critical topographical features, such as high hills or mountains. High ten-



Figure 58. Airfield sited on a marine terrace (France).

sion wires, roads, and railroads crossing the flightway near the runway are dangerous mental and physical hazards to pilots.

d. Meteorological conditions (wind, rainfall, fog, snow frost action).

e. Drainage.

f. Topography. A site with favorable topography is one located on high ground, with sufficient slope for natural cross drainage as well as longitudinal drainage and a reasonably smooth surface requiring little earth-moving.

g. Clearing, grubbing, and stripping required. A large open area surrounded by sufficient covered areas to conceal all activities is ideal. Ground cover in areas adjacent to the flight strip is especially desirable to provide natural concealment for parked aircraft, dumps, and bivouacs and other installations.

h. Soil characteristics. The type of soil determines the type of equipment required for construction, drainage characteristics, effects of adverse weather, and the subgrade bearing capacity that can be obtained.

i. Availability of gravel, sand, coral, or other materials for borrow excavation.

j. Water supply. Large quantities of water are required in both the construction and operation of airfields.

k. Camouflage requirements. A desirable site is one that avoids identifying landmarks and affords cover for installations and aircraft at dispersed locations.

116. Information Requirements

Higher headquarters will provide detailed studies of the airfields in an area of operations. This information is contained in the National Intelligence Survey and in such USAF publications as *Airfields and Seaplane Stations of the World*. Detailed studies of particular airfields in local areas will be prepared by intelligence personnel. Pertinent information to be included in a terrain study should include the following:

a. Existing Airfields.

- (1) Location (map coordinates, elevation, distance and direction from nearest city or town, principal landmarks, name if any).
- (2) Category (emergency landing strip, refueling and rearming strip, fighter field, bomber field, heliport, and civilian secondary airport).
- (3) Characteristics of site (type of terrain, character of soils, special aspects of weather and terrain differing from country-wide or regional conditions).

- (4) Detailed layout (sketch) of runways, taxiways, parking and service areas.
 - (5) Runways.
 - (a) Identification.
 - (b) Length of runway and overrun; extensibility.
 - (c) Width of runway, overrun, shoulders.
 - (d) Type and depth of surfacing and base.
 - (e) Type and adequacy of drainage (ditches, subsurface drains).
 - (f) Load capacity (in pounds, or aircraft type).
 - (g) Gradient.
 - (h) Present condition.
 - (6) Taxiways and parking (dimensions, type and depth of surface material and base, load capacity, condition).
 - (7) Detailed description of operating area; improvements planned or under construction.
 - (8) Facilities.
 - (a) Buildings (type, material, dimensions).
 - (b) Maintenance and repair (number and extent of buildings and numbers and types of equipment used for airfield maintenance).
 - (c) Fueling (number and capacity of tanks, above or below ground).
 - (d) Electricity supply.
 - (e) Water supply.
 - (9) Related transportation (railroad, road, water; details about type, location, and capacities of transportation facilities available).
- b. Airfield Construction Sites.*
- (1) Topography.
 - (2) Prevailing meteorological conditions.
 - (a) Wind (direction, intensity of prevailing wind; local peculiarities).
 - (b) Rainfall (average by months; wet seasons; intensity, duration, and frequency of rainfall).
 - (c) Other aspects (temperature variations, storms, fog, and ground haze).
 - (3) Availability of local construction materials.
 - (4) Water supply.
 - (5) Clearing and grading required.
 - (6) Drainage conditions and required improvements.
 - (7) Soil classification.
 - (8) Flight obstructions.

Section VI. WATER TERMINALS

117. General

a. Water terminals (ports) may range in size from beaches suitable only for landing craft to giant complexes extending along many miles of coastline. They usually constitute key terrain features and primary objectives in military operations. FM 55-51 gives detailed information about the organization and operations of water terminals.

b. Major water terminals (fig. 59) normally are characterized by deep harbors protected from storms and freedom from ice in the winter months. The rail and road networks of the area usually extend from the terminals inland to developed portions of the country. Large terminals are surrounded by commercial, industrial, and shipbuilding areas.

c. Water terminals are the subject of special studies prepared by technical intelligence specialists of the Transportation Corps and the Corps of Engineers (the Board of Engineers for Rivers and Harbors and the Army Map Service).

118. Military Considerations

a. Large water terminals are highly vulnerable to attack by nuclear weapons. When the enemy has a nuclear weapon capability, logistical support is provided through a number of dispersed small terminals, often little more than beaches developed to meet minimum requirements. Terrain studies should include an evaluation of all suitable locations for such terminals, indicating their physical characteristics, relative usefulness, and estimated capacities. A large-scale amphibious operation may include a number of separate secondary landings to secure beaches that are suitable for dispersed logistical terminals.

b. Detailed information about established water terminals usually is contained in terrain studies prepared at the highest levels. These form the basis for studies made in connection with specific operations. The existing water terminals are evaluated as to their usefulness in support of proposed plans and their present physical condition. If an enemy-held terminal is to be used by friendly forces after its seizure, particular attention is given to the essential structures and facilities that should be spared from destruction, if practicable, during the preliminary bombardment and assault.

119. Information Requirements

The information about a water terminal which is most essential in preparing a terrain study will depend upon the features that are of the greatest concern in a specific operation. The information required may include—

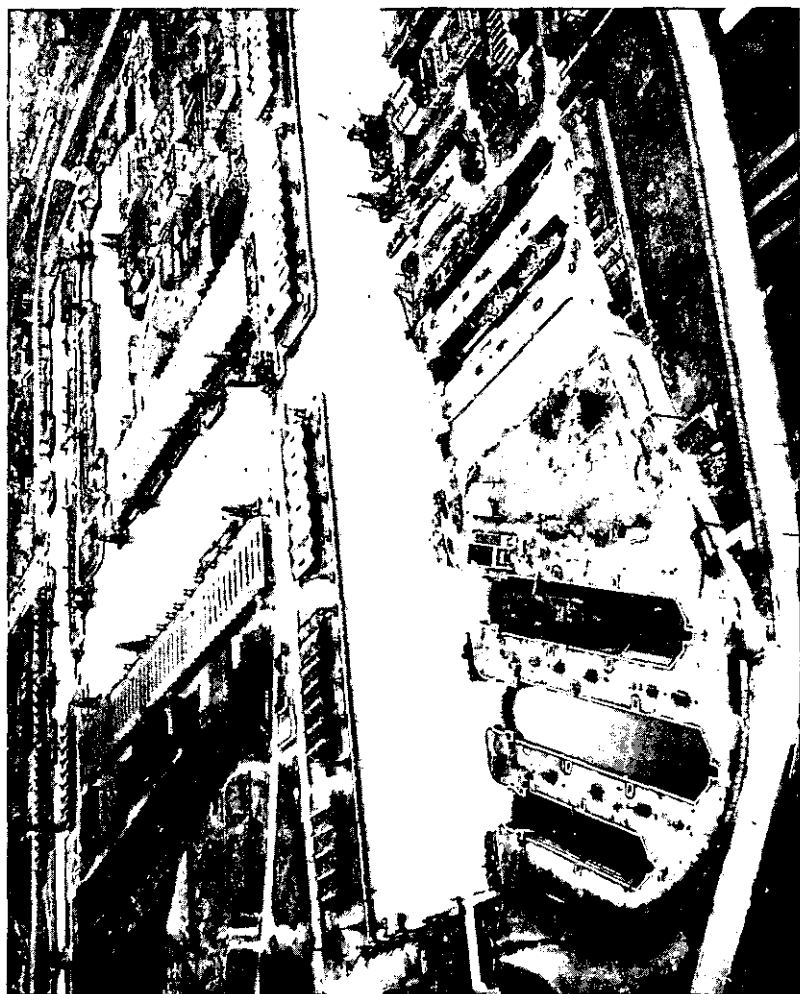


Figure 59. Typical large water terminal (port).

- a.* Name, location by map references and coordinates.
- b.* General characteristics (open roadstead, partly inclosed bay, landlocked harbor, sheltered area behind a barrier reef, and river).
- c.* Entrance and approach channels (controlling depth, length, width).
- d.* Breakwaters (position, length, construction).
- e.* Description of harbor.
 - (1) Type.
 - (2) Harbor and channel depths.
 - (3) Extent of silting.
 - (4) Nature and frequency of maintenance dredging.
 - (5) Location and nature of anchorages.
 - (6) Underwater obstructions.
 - (7) Pilotage information.
- f.* Bridges regarded as shipping obstructions (location, type, horizontal and vertical clearances at mean low water).
- g.* Hydrographic and weather conditions.
- h.* Adjacent beaches usable by landing craft (location, length, type, gradient, and accessibility).
- i.* Cargo-handling facilities.
 - (1) Wharves, piers, and quays (type, function, structural features, cargo-handling machinery, road and railroad connections, utilities, mooring facilities).
 - (2) Wet docks and semitidal basins.
 - (3) Mechanical handling facilities.
 - (4) Harbor-service craft (type, function, number).
- Repair facilities.
 - (1) Repair yards.
 - (2) Graving docks.
 - (3) Floating docks.
 - (4) Marine railways.
- k.* Storage facilities.
 - (1) Location, type of commodities stored, type of construction, capacity, transportation connections, fire protection, special handling equipment.
 - (2) Cold storage facilities (temperature, daily ice capacity).
 - (3) Grain storage facilities.
 - (4) Bulk liquid storage (capacities in barrels).
 - (5) Open storage (location of suitable areas, rail and road connections, approximate capacity).
 - (6) Petroleum and coal storage (location, type, capacity, bunkering facilities).
 - (7) Special storage facilities for explosives and ammunition.
- l.* Clearance facilities (rail lines, highways, inland waterways, pipelines).

- m.* Water supply (availability, quality, method and rate of supply).
- n.* Electric power and lighting (availability, source, and characteristics of current).
- o.* Capacity of the terminal as a whole, under both normal and present conditions.
- p.* Data needed for major repairs and improvements; vacant areas available for expansion.
- q.* Availability of trained, reliable personnel.

Section VII. HYDRAULIC STRUCTURES

120. Types

a. General. Hydraulic structures include those designed for flood control, hydroelectric powerplants, and water storage and to facilitate the use of waterways (fig. 60).

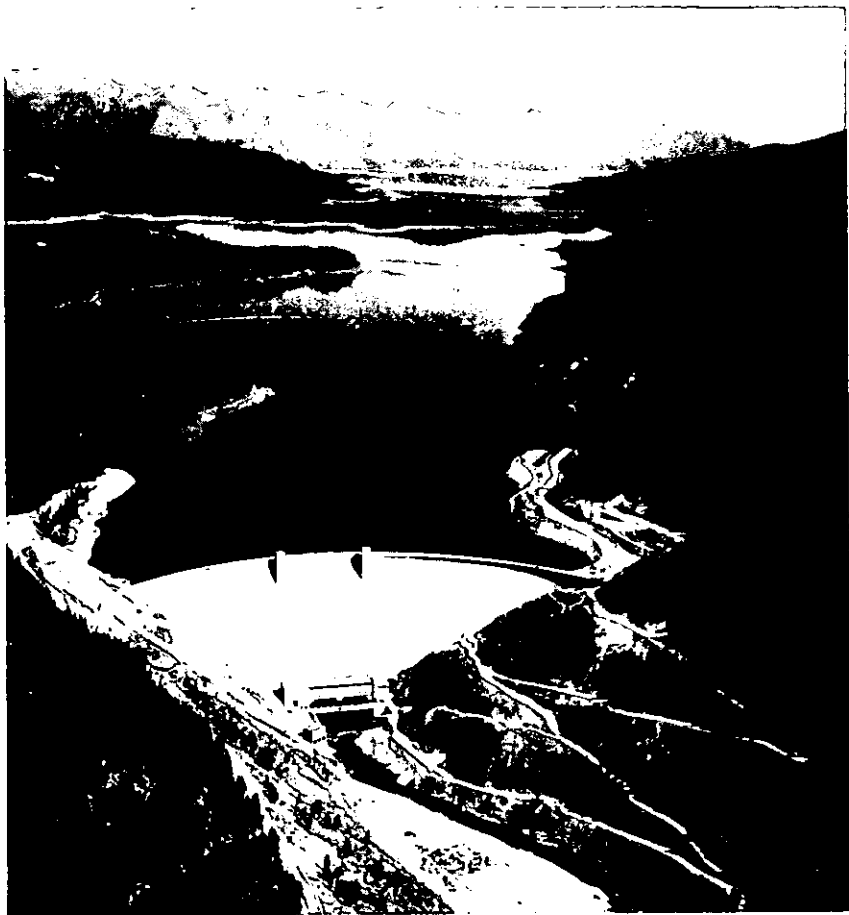


Figure 60. Dam and hydroelectric powerplant (Hungry Horse Dam, Montana).

b. *Flood Control.* The principal structure employed in flood control is the *artificial levee*, an embankment built along a river course to prevent flooding of the adjacent country during high water. It may be 20 feet or more in height, and usually is made by packing layers of earth upon a foundation, with grass planted on top of the levee to hold the soil. The levee may be faced with concrete. Usually an artificial levee is constructed some feet in rear of the river banks so that the river will have a wider channel during flood periods.

c. *Water Storage.*

(1) *Dams.*

- (a) Earth dams for reservoirs frequently are built of layers of homogeneous material with a center core of puddled clay or other impermeable material. Usually the inner surface is paved with stone or concrete as a precaution against erosion, and the outer surface is covered with grass to bind the surface and to protect it against the weather.
- (b) Dams across rivers and deep ravines or where there is considerable width and height, usually are made of stone masonry or concrete. They are built either straight across the river or in the form of an arc, the convex side fronting the stream.

(2) *Reservoirs.*

- (a) A *reservoir* is a wholly or partly artificial lake used for water storage. Reservoirs are utilized for municipal water supply systems, on rivers to aid in flood control, on canals to maintain the water level for navigation, and in hydro-electric installations to insure a constant water supply.
- (b) The reservoir may have a lining of clay or other impervious material to prevent water seepage. The embankments or retaining walls may be of earth, loose rock, or masonry. Distributing reservoirs in municipal water systems sometimes are built of masonry or reinforced concrete. They serve to take care of fluctuations in demand and as a reserve in case of interruptions at the source. In reservoirs with earth embankments, overflow is provided for by a *waste weir* or canal, to carry off surplus water. When the reservoir is formed by a masonry dam across a river, the surplus water may be allowed to flow over the top, or spillways may be provided (fig. 61).

d. *Waterways.* The dominant feature of developed waterways is the *canal lock*. A *lock* is an enclosed stretch of water with a gate at each end used to raise or lower vessels from one water level to another. When a vessel is to pass from a low level to a higher one, the water in the lock is lowered until it is level with that in which the ship is floating. The vessel is moved into the lock and the gate is closed. Water

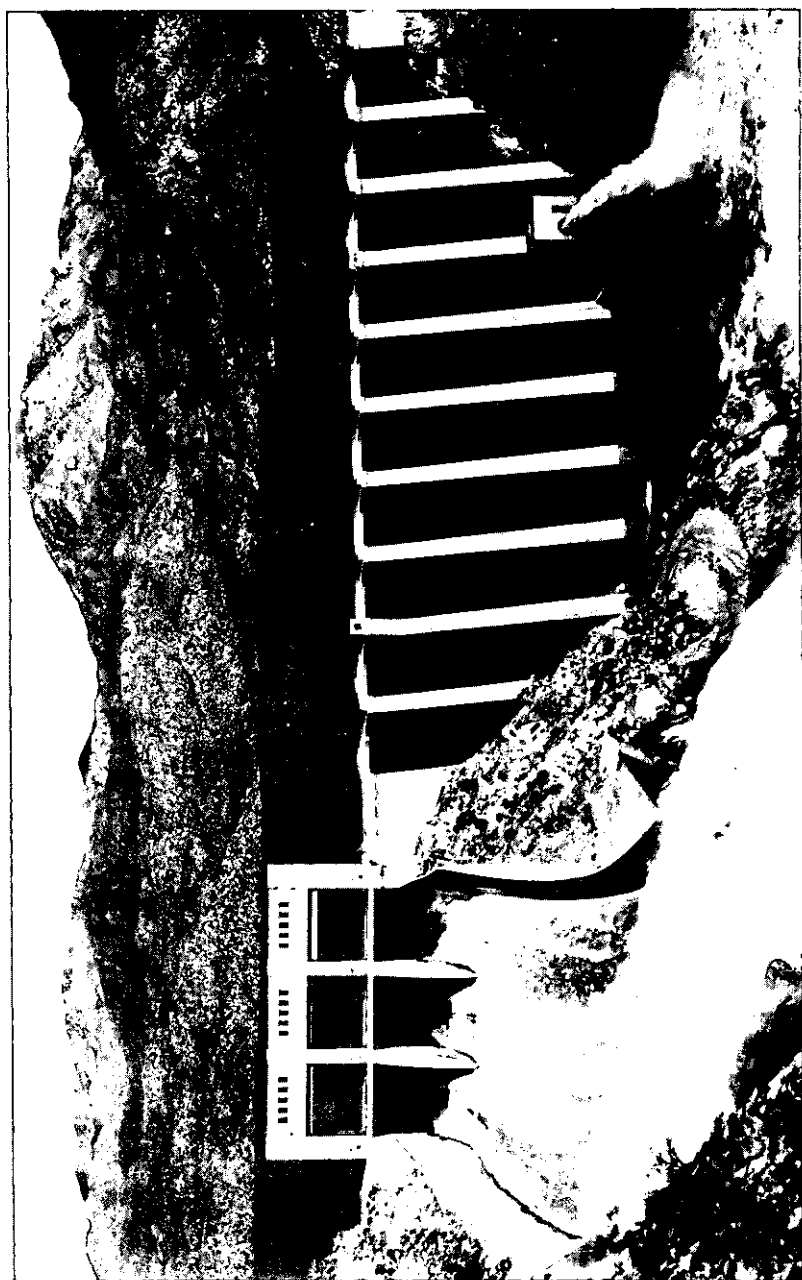


Figure 61. Spillway, storage dam (Bartlett Dam, Arizona).

is then allowed to enter the lock until it reaches the higher level, when the gate at the other end is opened and the vessel passes through. This procedure is reversed when the vessel goes from a higher to a lower level. Many locks have an intermediate set of gates so that only part of the lock is used for smaller vessels. Usually the water passes through culverts built into the lock walls and is controlled by sluice gates powered by hydraulic or electric power. Lock gates are made of either steel or wood. A pair of gates meets in the center of the lock entrance. When closed, the gates form an arc with the convex side toward the pressure of the water. The lift of a canal lock may be 40 feet or more.

e. Polders. Areas with an extensive network of reservoirs, canals, and levees may create a major problem in operations. The most notable of these areas are the polders of Belgium and The Netherlands, which have been reclaimed from the sea by artificial levees called *dikes*. The terrain is traversed by numerous canals and basins that drain the excess water and serve as navigation routes. The surplus water empties into the sea at low tide. In places where the water courses lead from the interior to the sea, they may be caused to overflow, creating a practically impassable obstacle to movement. In the interior, the polders greatly limit the landing areas suitable for airborne forces. When the dikes are destroyed, the cultivated areas are inundated. In these areas tanks and vehicles bog down, there is no cover for infantry, and the water is too shallow for boats.

121. Military Considerations

a. The military importance of hydraulic structures arises from the extensive flooding that may be caused by their destruction. Vast areas may be inundated by the destruction of a large dam or the artificial levees along a major river. Releasing the waters of even a small dam may flood sections of roads and railways or increase the width and velocity of a stream so that crossing operations are impeded. Hydraulic structures in enemy territory may be destroyed by aerial bombardment so as to cause these effects, or they may be seized by airborne forces before the enemy can demolish them.

b. Hydraulic structures are vulnerable to sabotage and guerrilla action. Those in territory under friendly control must be carefully guarded and subject to strict security precautions.

122. Information Requirements

The type of information that is required concerning a particular hydraulic structure will depend upon whether plans call for its defense, seizure, destruction, or reconstruction. Usually technical specialists are employed to prepare detailed studies of each structure that is being considered. In general, basic information includes—

- a. Location and name.
- b. Function: navigation, power, flood control, irrigation, water supply.
- c. Construction features: design type, materials, height, width, mechanical equipment, capacity.
- d. Extent and nature of repairs necessary.
- e. Security requirements.
- f. Effects of destruction upon the surrounding area.

Section VIII. BUILDINGS AND URBAN AREAS

123. Buildings

a. *General.* The design and construction of buildings are influenced by climate, available materials, function, and the cultural development of the native inhabitants. In areas with a tropical climate and primitive agriculture, for example, buildings usually are only crude huts made of woven grass, sticks, and mud. Buildings in desert oases are made of clay with thick walls, so that they are cool in summer and fairly warm in winter. In dry climates, where suitable timber is scarce, a wooden structure is a rarity and buildings are constructed from stone, adobe clay, or turf. Where there are cold winters, buildings will be solidly constructed of stone and wood.

b. *Military Considerations.*

- (1) The military significance of a building or group of buildings depends upon the mission or purpose of the study. A particular building may have value as an obstacle, a defensive strongpoint, or as a possible storage, headquarters, medical, or maintenance installation.
- (2) The structural features of a building comprise its construction characteristics, such as the predominate materials used, size and height, fire resistance, and architectural design. These features must be evaluated when considering either the use or the destruction of a building. The materials in a building may be useful for other construction. Brick, stone, and masonry buildings, when demolished, create rubble that may make formidable obstacles, or may provide concealment and cover for troops. Flimsy wooden buildings of the oriental type are highly flammable and may be remunerative targets for incendiary shells and bombs. Fires spread rapidly, making areas with buildings of this kind untenable. Since the fires are an obstacle to an attacker, they may be employed as a weapon by the defender. The height and number of stories in a building are significant features when selecting observation points.
- (3) Buildings used for specialized functions in the community may be adapted for similar military uses. These include

garages and other repair facilities, stadiums, theaters, auditoriums, warehouses, transportation terminals, and schools. Wherever possible, structures of religious or artistic importance are usually designated before an operation by civil affairs/military government agencies, and their employment for military purposes is prohibited.

- (4) Buildings made of solid masonry, concrete, and steel may be organized into defensive strongpoints. Substantial structures with deep basements provide varying degrees of cover from air or artillery attack. The protection against nuclear effects offered by buildings varies according to the type of construction, flammability, distance from ground zero, and many other factors. Personnel in buildings will be protected from the thermal radiation effects of a nuclear weapon and will receive some degree of protection from nuclear radiation effects. Casualties from secondary blast effects are caused largely by falling walls and ceilings and flying glass.

c. Information Requirements.

- (1) Location and function (residence, store, warehouse, factory, school, government headquarters, and communication center).
- (2) Structural features (materials, foundations, roof, bearing capacity of floors, exits, and basement).
- (3) Layout and capacity (floor plans, areas, cubages).
- (4) Utilities.
- (5) Possible military uses.
- (6) Security features (estimated capability for withstanding bombardment by conventional and nuclear weapons).
- (7) Needed repairs or improvements for military use.

124. Urban Areas

a. General.

- (1) An *urban area* is defined as a concentration of structures, facilities, and population which forms the economic and cultural focus for some larger area. Usually the inhabitants do not depend upon agricultural activities for their basic economy. A city or town may have a number of functions that make it significant. It may be primarily industrial, commercial, or recreational; the headquarters of government institutions; a port or railway center; or the location of an important cultural feature, such as a cathedral, university or historical landmark.
- (2) A large urban area usually has a *metropolitan area* that includes various surrounding settlements or suburbs whose daily economic and social life is connected with or influenced by the city.

- (3) Terrain intelligence concerning an urban area covers its general description and importance; physical characteristics; external communications; services and utilities; and major industries, including storage facilities.

b. Topography. The topography and geology of the urban area and its environs are significant elements in the terrain study. Topography exerts a major influence upon the size and pattern of the populated area; the location of external communications; the possibility of inundation or other natural disaster; and the defense that can be made against possible land, waterborne, and air attacks. The *development pattern* of an urban area is the physical adjustment of the area to its topography, as influenced by past events, current economic forces, and social trends.

c. Classification of Area. The elements comprising an urban area may be classified according to the predominant construction and function of the buildings and other structures.

- (1) *Construction.* Where no gaps exist between buildings, as in the business districts of larger towns and cities, this is described as *block type* construction. *Detached and semi-detached building areas* are those where the buildings are spaced relatively close together, as they are in low- and middle-cost housing areas. *Isolated housing areas* are found on the approaches to towns and cities where individual or small groups of homes are located in the midst of large open areas. This is typical of the suburbs of the average city.
- (2) *Function.* Normally a city includes separate areas largely devoted to one type of use. The major functional areas may be distinguished as follows:
 - (a) *Industrial areas* comprise a grouping of individual plants and loft buildings, with associated storage and transportation facilities, devoted to manufacturing activities.
 - (b) *Commercial areas* are composed of a concentration of retail and wholesale establishments, financial institutions, office buildings, hotels, garages, public buildings, and light manufacturing plants.
 - (c) *Residential areas* consist predominantly of dwellings with interspersed shopping centers; churches; schools; and fire, police, telephone, and power stations.
 - (d) *Transportation and storage areas* contain the terminal, transshipment, storage and repair facilities and service buildings associated with general movement by rail, water, road, pipeline, or railway.
 - (e) *Governmental-institutional areas* include the grounds, structures, and facilities related to governmental administrative offices, hospitals, schools, colleges, homes for the aged or orphans, sanitariums, monasteries, penal or re-

search institutions, and similar establishments which usually form distinctive and generally extensive areas.

- (f) *Military areas* contain structures and facilities for billeting, quartering, defense, hospitalization, storage, and repair, which are devoted exclusively to military use.
- (g) *Open areas* comprise land not occupied by buildings and not assigned to any industrial, transportation, business or residential activity. Developed open areas include cultivated land, parks, recreation areas, and cemeteries. Undeveloped open areas include swamps, woods, beaches, and other vacant land.

d. General Military Considerations. The decision to bypass or to seize and occupy an urban area depends upon the mission of the unit concerned. Cities and towns may be important objectives because they represent centers of population, transportation, manufacture, and supply. Port cities and railroad centers are given a priority status as targets and objectives in both tactical and strategical planning. Unless the mission requires otherwise, a city or town usually is bypassed and isolated, since it is an obstacle that canalizes and impedes both attacking and counter-attacking forces. Urban areas are vulnerable to destruction by air or artillery bombardment and may be neutralized by chemical, biological, or radiological contamination. Fires started by nuclear weapons or incendiaries may make them untenable. Combat within built-up areas (described in detail in FM 31-50) is characterized by—

- (1) *Limited observation and fields of fire.* Because the opposing troops usually are close to each other, effective close support by artillery and combat aviation is limited. The available cover is rigid and set in straight lines, so that all movement in the open usually can be observed unless it is concealed by smoke, dust, or darkness. Smoke may be used to provide concealment, limit observation, and achieve deception and surprise. In a built-up area, smoke remains effective longer than in open areas. It is usually difficult to observe and locate enemy weapon positions because of the dust caused by the impact of projectiles and explosive charges and the smoke from explosions and fires.
- (2) *Increased concealment and cover.* Weapons and troops may be concealed in built-up areas, and ample cover is usually available against small-arms fire. Cover from air and artillery bombardment, however, is provided only in buildings of particularly substantial construction.
- (3) *Limited movement.* The mobility and maneuverability of infantry, artillery, and armor are greatly limited in built-up areas. Vehicular traffic is canalized, and extremely vulner-

able to ambush and the close-range direct fires of enemy weapons.

- (4) *Restricted communications.* It is difficult to maintain efficient communications in built-up areas. Normally control must be decentralized to small-unit commanders. Tall buildings and those with steel frames may interfere with radio communication. Reliance usually must be placed upon wire and foot messengers.

e. Attack in Urban Areas.

- (1) Detailed information concerning the enemy, his defenses, the terrain surrounding the town that is under his control, and the layout of the built-up area is essential to the commander in making plans and decisions for an attack. These plans should be based upon the latest and most complete terrain intelligence available. Particular emphasis is placed upon determining the location of covered approaches to the urban area, the location of public utility plants and their security measures, and the location and nature of all obstacles.
- (2) The final objective of the attacking force is to seize the entire urban area. Within the area, objectives for individual units include key installations such as railroad stations, telephone exchanges, and public utility plants, which are often organized as centers of enemy resistance.
- (3) The attack of an urban area begins with the seizure of terrain features which dominate approaches to the city, followed by the seizure of buildings on the near edge to reduce or eliminate the defender's observation and direct fire upon the approaches. The last phase is a systematic advance through the area until it is fully secured.

f. Defense in Urban Areas. Urban areas favor the defense. Whether or not a city or town is organized for defense depends upon its size, relation to the general defensive position, and the amount of cover it offers for occupying forces. Cities, towns, and villages constructed of flammable materials provide little protection and may become a hazard to the defender, while buildings of solid masonry can be developed into well-fortified defensive positions or centers of resistance. Cellars, sewers, subway tunnels, thick masonry walls, and reinforced concrete floors and roofs provide cover for the defender during heavy bombardments. A heavy aerial or artillery bombardment of a city before an attack actually may serve to strengthen its defenses. The fallen rubble may give the defender increased protection, and may make the streets impassable for armor.

g. Information Requirements. Information about an urban area requires the compilation of many factors, each devoted to a particular aspect of the area, such as the transportation services, utilities, billet

ing facilities, or industries. A terrain study should include annotated maps, plans, and photographs, with an accompanying text giving that which cannot be shown graphically. Information that should be included under each category is outlined below. The scope of the information that is presented is limited by the purpose for which the study is being prepared. The text should include information in the following categories, as pertinent:

h. General Description.

- (1) Name and location (geographic and grid coordinates).
- (2) Population (number and trend, significant ethnic and religious segments).
- (3) Principal functions (communications and industry).

i. Physical Characteristics.

- (1) Topography and geology of area and environs.
- (2) General cross-country movement of environs.
- (3) Climate (mean temperatures and rainfall).
- (4) Landmarks (natural and manmade).
- (5) Extent of built-up areas (present boundaries, recent additions, probable future expansion).
- (6) Functional areas.
- (7) Structures.
 - (a) Characteristics of predominant types of buildings (height, number of stories, principal construction materials).
 - (b) Structure density (ratio of roof coverage to gross ground area; as warranted, ratio of roof coverage to ground area within each of the functional areas).
 - (c) Principal buildings.
- (8) Susceptibility to fire and shock.
- (9) Damaged or destroyed areas (delineation and general character).
- (10) Significant ethnic and religious groupings (delineation and general character of the areas occupied).
- (11) Streets.
 - (a) Surface, condition, and pattern.
 - (b) Prevailing widths (curb to curb and building to building).
 - (c) Names and alinement of through routes and principal streets.
 - (d) Location and characteristics of bridges, tunnels, and ferries.
- (12) Local roads (alinement and characteristics of roads in environs).

j. External Communications.

- (1) *Roads.* Identification of the roads that enter the urban area, the routes that bypass it, and the road distances to the nearest important town on each route should be shown on maps. In

the text, the importance of the roads as avenues of movement to and from the town should be discussed. Annotations on city maps should locate and identify highway structures, ferries, and road service facilities.

- (2) *Railways*. Maps should show the railways that enter or bypass the urban area, with distances to the nearest important towns. Textural notes should discuss the importance of the railways as transportation arteries to and from the town. Annotations on city maps should locate and identify railway structures and crossings (bridges, tunnels, and ferries) and such railway structures as passenger and freight stations, yards and sidings, repair shops, turntables, and "y" track.
- (3) *Inland waterways*. Identification of each navigable water route (river, lake, or canal) which borders or passes through the urban area and the waterway distance to the nearest upstream or downstream port should appear on maps. The importance of the waterway should be discussed in the accompanying text. Annotations on city maps should locate and identify important waterway structures. Information on shipyards is included with that on the industries of the urban area.
- (4) *Airfields*. The location of each airfield and seaplane station which serves the urban area should be shown on city maps or, if beyond the limits of the city, on topographic maps. Textural notes should indicate the adequacy of the existing air service, list each commercial airline which serves the area, and provide information on the frequency of service. Information about airfield classification is presented in TM 5-250.

k. Urban Services and Facilities.

- (1) Water supply.
 - (a) Sources (name, location, type, capacity).
 - (b) Treatment plants (number, type, capacity, and location).
 - (c) Storage (name, location, type, capacity).
 - (d) Method of distribution.
 - (e) Consumption (in terms of minimum and average requirements per person per day, whether any rationing is practiced and during what periods, annual consumption).
- (2) Sewage disposal (sanitary, storm, industrial waste).
 - (a) Collection methods (type, adequacy).
 - (b) Treatment plants (type, location).
 - (c) Disposal methods (including location of dumps or incinerating plants).

- (3) Garbage and trash disposal.
 - (a) Collection methods.
 - (b) Treatment plants (type, location).
 - (c) Disposal methods (including location of dumps, incinerators, and processing plants producing fertilizer).
- (4) Major hospitals.
 - (a) Name, location, and specialization, if any.
 - (b) Bed capacity.
 - (c) Age and condition.
- (5) Electricity.
 - (a) Sources (name, type, location, installed capacity).
 - (b) Substations (name, type, location, capacity).
 - (c) Distribution current characteristics.
 - (d) Number of consumers.
 - (e) Yearly consumption.
- (6) Gas.
 - (a) Type.
 - (b) Sources (name, location, capacity).
 - (c) Storage (type, location, capacity).
 - (d) Extent of distribution.
 - (e) Number of consumers.
 - (f) Yearly consumption.
- (7) Storage.
 - (a) Open (large open areas within or adjoining the town suitable for use as open storage and supply dumps).
 - (b) Covered (warehouses and sheds).
 - (c) Cold (refrigerated storage; ice plants with cold-storage facilities).
 - (d) POL (number of tanks or reservoirs at each location; capacities in U.S. barrels).
 - (e) Explosives (magazine and bulk-storage facilities; types and quantities of explosives stored).
- (8) Ice-manufacturing plants (name, location, capacity).
- (9) Billeting and accommodation. (Total capacity for billeting and accommodation in military barracks, hotels, public buildings, school and institutional buildings, and other structures; total capacity of bakery and laundry establishments; availability of baths and swimming pools suitable for troop use. Location, capacity, and type of each structure).
- (10) Internal transit system (type, extent, location of main terminal, and maintenance facilities).
- (11) Fire protection (organization and manpower of fire department; quantity and type of equipment).

- (12) City government (type, personalities, location of facilities).
- (13) Civil defense (organization and manpower; quantity and type of equipment).
- (14) Industry.
 - (a) Major industrial activity (for each industry, the type, number of plants, number of employees, and importance).
 - (b) Significant manufacturing plants.

125. Utilities

a. Special Studies. Detailed intelligence about the utilities of an urban area is necessary in order to plan its utilization for military purposes. Special studies by technical personnel should be prepared covering each of the following:

- (1) Water supply.
- (2) Sewage disposal.
- (3) Electric power.
- (4) Illuminating gas.
- (5) Public transportation system.
- (6) Communications.
- (7) Fire protection.
- (8) Trash and garbage disposal.

b. Use of Special Studies. Intelligence studies covering utilities form the basis for estimating requirements for operating and maintenance personnel, the equipment and replacement parts needed for repairs and operation, and the amount of military equipment that must be provided to supplement the existing utility installations. These studies also furnish a guide to selecting the most profitable targets for air attack. The destruction of key utilities is given a high priority in planning aerial bombardments, since a breakdown in these services results in disorganization of the enemy defenses and is highly damaging to civilian morale.

c. Information Requirements.

- (1) The amount and type of information about the utilities of an urban area that is required will depend upon the purpose for which the area is being considered. If it is intended to develop a city into a major logistical base, complete information concerning the capacity, state of repair, and operating methods of each utility will be necessary. The capability to supply minimum civilian needs as well as military requirements must be evaluated.
- (2) Detailed information requirements for each type of utility are contained in FM 5-30. General surveys of utilities should include the following information about each service or installation—

- (a) Physical condition.
- (b) Adequacy for normal load.
- (c) Portion of present capacity that could be diverted to military use.
- (d) Repairs essential for military utilization.
- (e) Safety and security provisions.
- (f) Availability of skilled, reliable civilian personnel.
- (g) General efficiency and dependability of the plant or system.

Section IX. NONURBAN AREAS

126. General

a. Populated areas outside towns and cities usually consist of farmsteads and small settlements. A *farmstead* is the dwelling and adjacent buildings associated with an individual farm. The characteristics of a farmstead reflect the climate of the area and the type of agriculture.

b. In rainy tropical climates, most of the inhabitants dwell along streams and waterways, the settlements being located on the bluffs, which are well-drained and exposed to the river breezes. The large rubber, coconut, or banana plantations are usually near the ocean or on the banks of navigable rivers, since roads and railways are few and difficult to maintain. Nonurban areas in dry subtropical climates are dominated by large cattle and sheep ranches, with individual farmsteads separated by miles of grazing land. In semiarid tropical climates, the native agriculture is largely pastoral, and the relatively few settlements consist of huts surrounded by mud walls or fences of thorny brush. Subarctic villages seldom consist of more than a dozen dwellings, with as much as 30 to 40 miles between settled areas.

c. In temperate climates, the buildings of a farmstead are detached from each other, while in areas with extremely cold winters the house, barn, and other outbuildings commonly are under one roof. The outbuildings of a farmstead in the tropics normally are few and small, because the animals remain outdoors all year. Small villages in the middle latitudes often consist of houses built in rows along the sides of a road or clustered around an open square, while in tropical climates the houses of a village usually are dispersed without any regular pattern.

127. Military Considerations

a. In general, the same considerations that are pertinent to an urban area (par. 124) also apply to nonurban areas.

b. Small settlements may be critical when they dominate routes of communication at fords, bridges, railway lines, or defiles (fig. 62).



Figure 62. Small settlement dominating a main route of communications.

Villages that are small in size may have considerable military significance because of a particular industry, mine, or other unique economic feature. They may be local markets and distribution centers serving a wide rural area and representing an important enemy source of food-stuffs and other supplies. A village with a small local population may be a resort area or the site of a university or similar large institution, capable of providing quarters and other facilities for large numbers of troops.

c. In tactical operations, it is occasionally necessary to secure or destroy small villages that have no direct military value but are used to provide concealment, supplies, and other support to guerrillas. The civilian inhabitants may have to be relocated in other settlements under military control.

d. The buildings of a farmstead furnish quarters for troops and shelter for storage and maintenance facilities. Stone buildings may be suitable for weapons emplacements and defensive strongpoints. Nearly all rural dwellings are within a short distance of a reliable source of water.

e. Cross-country movement frequently is hampered by obstacles such as stone fences, retaining walls, irrigation ditches, and paddy fields. Features such as high fences, hedgerows, embankments, and ditches may offer limited cover and concealment to individuals and small groups.

128. Information Requirements

The particular information about a farmstead or small village that is required will depend largely upon the mission of the unit concerned. Basic information requirements should include—

- a.* Location ; relation to local terrain features.
- b.* Size (area, population, pattern of streets or roads).
- c.* Facilities for quarters, maintenance and repair installations.
- d.* Predominant construction materials.
- e.* Utilities.

CHAPTER 8

MILITARY ASPECTS OF THE TERRAIN

Section I. GENERAL

129. General

a. In conducting an operation, the commander must determine how the terrain can be used most effectively by his forces, how it may affect the enemy's capabilities, and how it may be exploited to interfere with the enemy. With the assistance of his staff, he considers the weather conditions, relief and drainage, vegetation, surface materials, and manmade features and their effects upon—

- (1) Observation and fields of fire.
- (2) Concealment and cover.
- (3) Obstacles.
- (4) Key terrain features.
- (5) Movement.
- (6) Avenues of approach.

b. The relative importance of various aspects of the terrain varies with the mission, the type of operation, the size and composition of the forces involved, and their weapons and equipment. Detailed intelligence concerning terrain features normally increases as the size of the unit diminishes. The commander of a field army, for example, may be concerned about the effects that an extensive mountain range will have upon a proposed campaign. A corps commander might be interested only in one mountain of the range, while the commander of a battle group would concentrate upon a particular group of foothills in his area.

c. When making a systematic study of the military aspects of an area, it is sometimes divided into natural subareas or, if there are no suitable natural boundaries, into subareas based upon the tactical plan. The military aspects of the terrain then are evaluated by each subarea from both the friendly and enemy points of view.

d. The characteristics and effects of key terrain features are discussed in FM 30-5.

130. Observation

a. *Observation* is the direct examination of terrain and military activities. It includes examination from ground and air by unaided vision and by vision assisted by optical and infrared devices and detection by photographs, radar, and sonic devices. In general, observa-

tions refers to the ability of a force to see the enemy under specified conditions of weather and terrain.

b. Observation is essential to bring effective fire upon the enemy, to control the maneuver of friendly troops, and to prevent surprise. From the viewpoint of observation, the best terrain is that which permits both long-range observation into enemy-held areas and close-in observation of the hostile forward elements. Usually long-range observation is found near the topographical crest of an elevated area, while close-in observation is obtained from a location near the military crest.

c. Fog, smoke, precipitation, heat refraction, darkness, manmade and natural features, and vegetation may limit or deny observation. The specific effects of these factors upon observation were discussed in the preceding chapters of this manual. They must be evaluated in determining the extent and type of observation that will be available to enemy and friendly forces at any given time and place. Supplemental means of observation or increased security measures may be necessary during periods of limited visibility.

d. The highest point on the terrain does not always provide the best observation, since variations in relief often create blind spots in the field of vision. The selection of observation points should be preceded by a careful study of the terrain based upon reconnaissance, topographic profiles, or stereographic examination of aerial photographs.

e. The effects of weather and terrain upon visibility are discussed in FM 30-5.

131. Fields of Fire

a. *Definition.* A *field of fire* is an area that a weapon or group of weapons can cover effectively with fire from a given position. When considering terrain in relation to fields of fire, the type of weapon determines what factors will be significant. The natural terrain must be evaluated according to its suitability for flat-trajectory weapons, high-trajectory weapons, rockets, and guided missiles, including those with nuclear capabilities. Chapter 7 should be consulted for the specific effects of terrain upon the fields of fire of weapons.

b. *General Requirements.*

- (1) The ideal field of fire for flat-trajectory weapons is flat or gently sloping terrain on which an enemy can be seen and which provides no protection for him within the effective ranges of the weapons. Broken terrain creates dead spots which flat-trajectory weapons cannot reach and furnishes cover and concealment for the enemy. Open terrain providing good fields of fire permits a unit to defend a wide front. Broken terrain makes it necessary to provide more

troops and weapons to defend a given frontage than would be necessary in open terrain.

- (2) The field of fire of high-trajectory weapons is limited only by very steep reverse slopes that the weapons cannot reach and by masks which permit the enemy to occupy positions in defilade.
- (3) Fields of fire can be improved by cutting or burning vegetation, demolishing buildings, and cutting lanes through woods. The time and labor required for such improvements should be considered when evaluating the terrain:

132. Concealment and Cover

a. Definitions. *Concealment* is the hiding or disguising of military installations or activities from enemy observation. *Cover* is protection from enemy fire, from both conventional and nuclear weapons.

b. Evaluation of Terrain.

- (1) Terrain is evaluated to insure the maximum use of concealment and cover. Terrain under enemy control is also studied, to determine how the concealment and cover that it provides can be nullified. In the attack, concealed and covered routes into the enemy position are sought to gain surprise and to reduce casualties. In the defense, concealment and cover are utilized not only to protect individual positions, but also to hide the general trace of the defenses, so that the attacking troops may be vulnerable to surprise by the location of defense positions and weapons fires.
- (2) When evaluating terrain from the viewpoint of the cover that it will provide, the characteristics of all the weapons used by the enemy must be considered. This includes their ranges, types of fire, and the relative quantities of each kind of weapon available to him.
- (3) Topography is the major factor influencing cover. Valleys, mountains, gullies, ravines, hills, and similar features provide cover from flat-trajectory weapons. Individuals and small units may secure cover from such terrain features as ditches, riverbanks, folds in the ground, shell craters, buildings, walls, railroad embankments and cuts, and highway fills. Cover from high-angle weapons usually is difficult to obtain. Caves, buildings of exceptionally strong construction, and the steep slopes of hills and mountains may offer some degree of cover, depending upon the capabilities of the weapons employed by the enemy. Nuclear thermal radiation travels by line of sight, so that it will be masked by hills, banks of ravines, and gullies. The extent of protection thus provided will depend upon the height of the explosion.

A nuclear blast wave curves around obstacles and is less affected by relief features.

- (4) Terrain features that offer cover also provide concealment. The greater the irregularity of the terrain, the more concealment it will furnish from ground observation. Lower echelons are concerned with the concealment of men, vehicles, weapons and emplacements; higher echelons, with the concealment of headquarters, supply dumps, airfields, and other major installations.

133. Obstacles

a. Definition. Obstacles are features of the terrain which stop, delay, or restrict military movement.

b. Types. According to their effects, obstacles may be classified as antipersonnel obstacles, antimechanized obstacles, underwater obstacles, and obstacles to the landing of aircraft. *Natural obstacles* comprise such features as unfordable streams, swamps, deep snow, cliffs, steep slopes, thick woods and undergrowth, flooded areas, boulder-strewn areas, lakes, mountains, and nontrafficable soils. *Artificial obstacles* include those prepared to delay or stop military movement, such as contaminated areas, minefields, trenches, antitank ditches or barriers, roadblocks, blown bridges, road craters, deliberately flooded areas, wire entanglements, and various types of beach and underwater obstacles. They also include manmade features that were not originally designed as obstacles to military movement, such as canals, levees, quarries, or reservoirs.

c. Employment of Obstacles.

- (1) The employment of obstacles is integrated with the overall scheme of maneuver and fire support. Both natural and artificial obstacles are utilized to channel, direct, restrict, delay, or stop an opposing force. Instructions for the employment of obstacles usually are included as an annex, termed the *barrier plan*, to the operation plan or order of divisions or higher units. FM 31-10 discusses the use of obstacles and the requirements of barrier plans.
- (2) A barrier plan provides for the most effective employment of obstacles to impede enemy movement along favorable routes of approach, divert advancing enemy forces towards routes favorable to defense counteraction, or compel the enemy to concentrate or disperse. Artificial obstacles must not be located where they would interfere with the proposed movements of friendly forces or with counterattack plans. They may be placed in considerable depth, so as to provide time for counterattacking troops to meet an enemy threat, and to force the enemy to expend time and strength at each barrier. To be fully effective, artificial obstacles must be kept under

observation at all times, and must be augmented by fire or explosives. Whenever possible, obstacles are sited so that they are under friendly observation but defiladed from enemy observation.

- (3) Local unit commanders are responsible for constructing obstacles for the close-in defense of their positions. Advice and technical assistance is provided by engineers, who also construct and install obstacles which require special skill and equipment.
- (4) The use of toxic chemical and biological agents and radiological contamination to supplement barriers or as obstacles, makes it possible to deny or restrict areas by contamination, to canalize enemy maneuver, or to contaminate enemy field fortifications so that they are untenable. Additional information about the employment of these agents is contained in FM's 3-5, 21-40, and 100-5.

d. Effects on Operations.

- (1) The effects of natural terrain features as obstacles to military movement are discussed in Chapter 7 of this manual. Artificial obstacles are described in FM's 5-15 and 31-10.
- (2) The location and extent of both natural and artificial obstacles must be considered by a commander in making his plans. He must decide how they will affect his mission, and how they may be utilized to assist him in accomplishing it. The tactical effect of an obstacle depends upon the type of operation, the weapons and equipment employed, and the size of the forces involved. A terrain feature that is a major obstacle for a company may be a minor obstacle to a battle group and no obstacle at all to a division.
- (3) Obstacles may either help or hinder a unit, depending upon their location and nature. For example, a deep creek lying across the axis of advance will slow up an attacker, but will provide defending forces with an advantage, since it delays advancing troops and exposes them to fire. Similarly, heavy woods in front of a position may provide infantry with a concealed route of approach but act as an obstacle to the movement of supporting tanks. In general, obstacles perpendicular to the axis of advance favor a defending force, while those parallel to the axis may give the attacker an advantage by protecting his flanks, although they will also limit lateral movement and his ability to maneuver.
- (4) In offensive operations, obstacles influence the choice of objectives, the avenues of approach to an objective, and the time and formation of an attack. Obstacles may be employed to contribute to flank security, impede counterattack, provide

additional protection for a section of the front that is not strongly manned, or assist in enemy entrapment.

- (5) Obstacles are employed in the defense to channel, direct, delay, or stop the movement of an approaching force. They may be used to delay the initial enemy advance toward the front and flanks of a position, delay the movements of enemy penetrating or enveloping forces, or canalize enemy penetrations into avenues of approach where they can be defeated or destroyed.

134. Avenues of Approach

a. *Avenue of Approach to a Terrain Feature or an Objective.* This is an area of terrain which provides a suitable, relatively easy route of movement for a force of a particular size and type. An avenue of approach should provide—

- (1) Ease of movement toward the objective.
- (2) Concealment and cover from the defender's observation and fire.
- (3) Favorable observation and fields of fire for the attacker.
- (4) Adequate maneuver room for the attacking force.

b. *Suitability and Ease of Movement.* The suitability and ease of movement of an avenue of approach depend upon—

- (1) The routes of communication.
- (2) Soil trafficability.
- (3) Concealment and cover.
- (4) Observation and fields of fire.
- (5) Obstacles.
- (6) Relationship of terrain corridors and cross compartments.

c. *Multiple Use of Avenues of Approach.* In some types of operations, in which maneuver is very limited by either weather or terrain, an avenue of approach may in itself be a key terrain feature. For example, in rugged mountainous terrain, one road along a valley may be the only route of supply and at the same time the most favorable avenue for approach for the major element of the attacking force. A river in the jungle may be the only transportation route, and thus a key terrain feature, an avenue of approach, and an obstacle.

d. *Avenues of Approach in Attack.* Usually an attack is directed toward securing dominating terrain early in the action. The avenue of approach that is most favorable for accomplishing this mission normally is assigned to the forces making the main attack. Whenever possible, the avenues of approach that are selected are those that avoid areas most strongly held by the enemy. In planning an attack, a study is made of the avenues of approach that might be used by the enemy for counterattacks and for reinforcing and resupplying his forces. These avenues can be determined by an analysis

of the terrain in its relation to the location of enemy reserves and supply routes.

e. Avenues of Approach in Defense. In planning the organization of defense positions, the terrain is evaluated to determine the avenues of approach that are most likely to be used by the enemy. These normally will be the avenues that lead toward key terrain features; provide good observation, fields of fire, concealment and cover, and either avoid or exploit obstacles. Defense positions are sited to deny such avenues of approach to the enemy. The avenues of approach that can be used by friendly forces in counterattacks also are evaluated.

f. Compartments. The effects of relief and drainage upon avenues of approach are considered in terms of *compartments*. A terrain compartment is an area bounded on at least two opposite sides by terrain features such as woods, ridges, or villages that limit observation and observed fire into the area from points outside the area. A terrain compartment includes not only the area enclosed but the limiting features as well.

- (1) *Delimiting lines* are imaginary lines drawn along limiting features from which ground observation into a compartment is limited. In compartments formed by woods and villages, these lines run at some point within the edge of the woods or village, depending upon the density of the woods, or the number and density of the buildings.
- (2) Compartments are classified according to the direction of movement of the forces operating in them. They are termed *corridors* (fig. 63) when the longer dimension of the compartment lies generally in the direction of movement, or leads toward the objective, and *cross compartments* (fig. 64) when the longer axis is perpendicular or oblique to the direction of movement.
- (3) Compartments are also classified as *simple* or *complex* (figs. 65 and 66). A complex compartment is one having a smaller compartment, or compartments, lying within it. This is the type most often encountered.

g. Corridors. Corridors, or ridges that form their limiting features, provide favorable routes of approach for an advancing force because the defender's lateral organization and fields of flat-trajectory fire are obstructed by the limiting features, which also decrease his ability to obtain mutual support between units and limit his observation. To the attacker, a corridor offers two types of approach: *valley approach* and *ridge approach*.

- (1) While a valley approach may provide concealment and cover the military crest of the limiting features on each side must be controlled to deny enemy observation and direct fire into

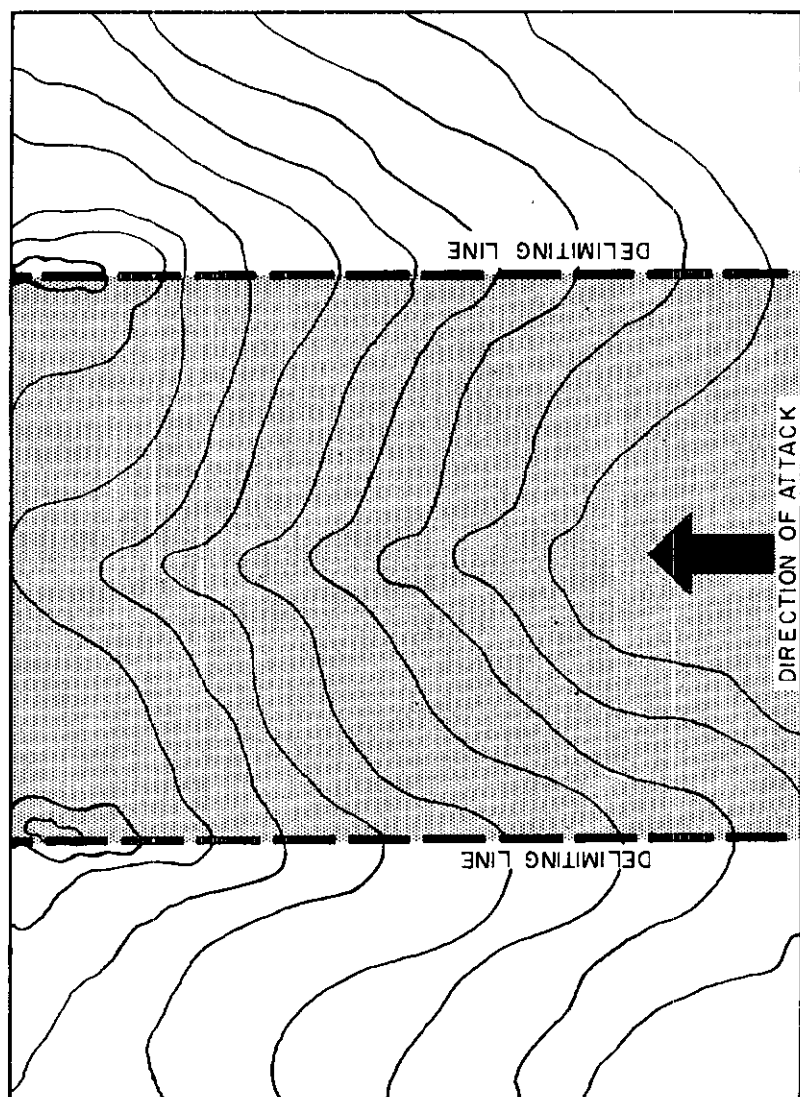


Figure 63. Terrain corridor.

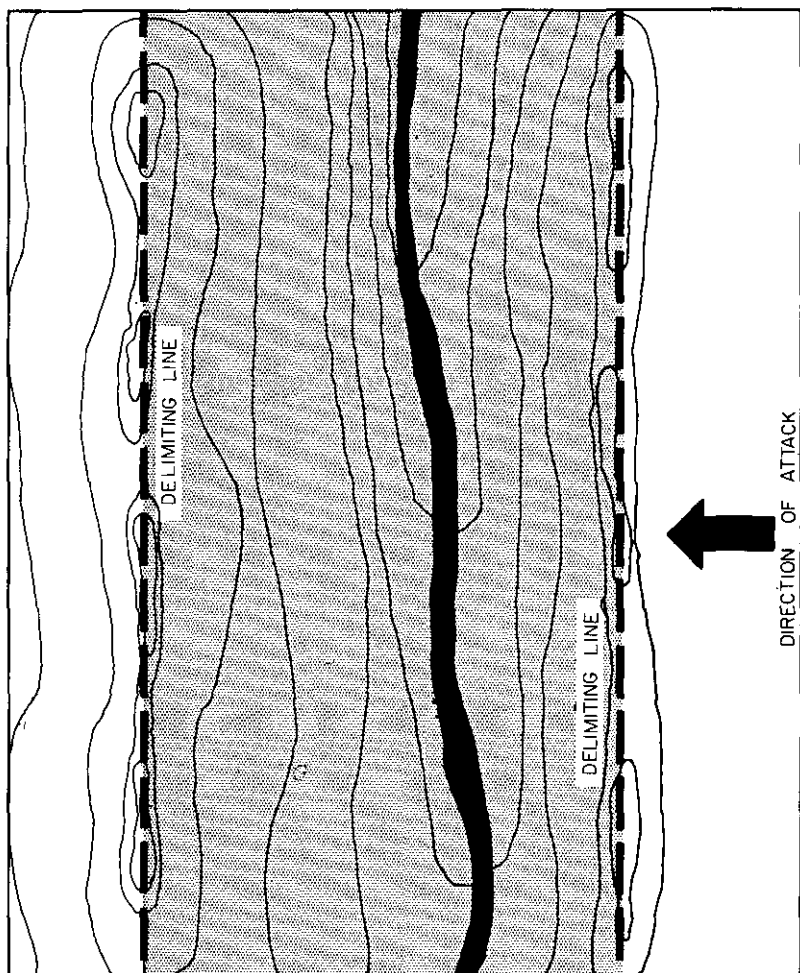


Figure 64. Cross compartment.

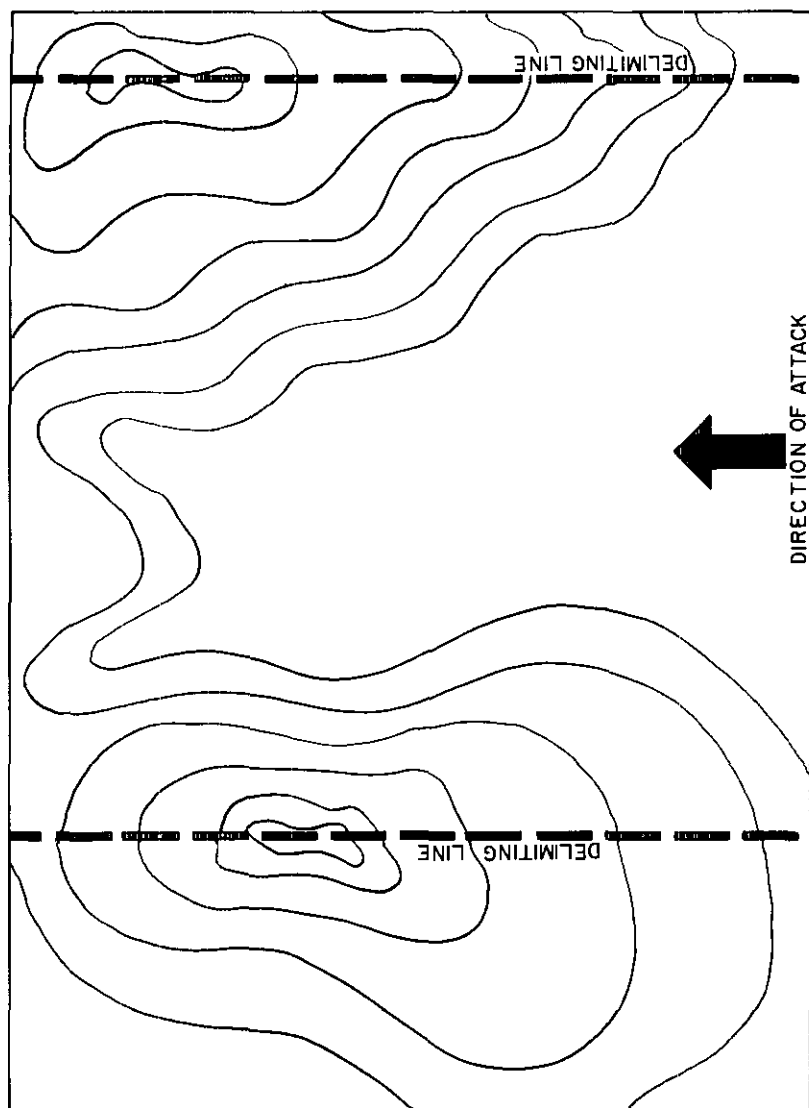


Figure 65. Simple compartment.

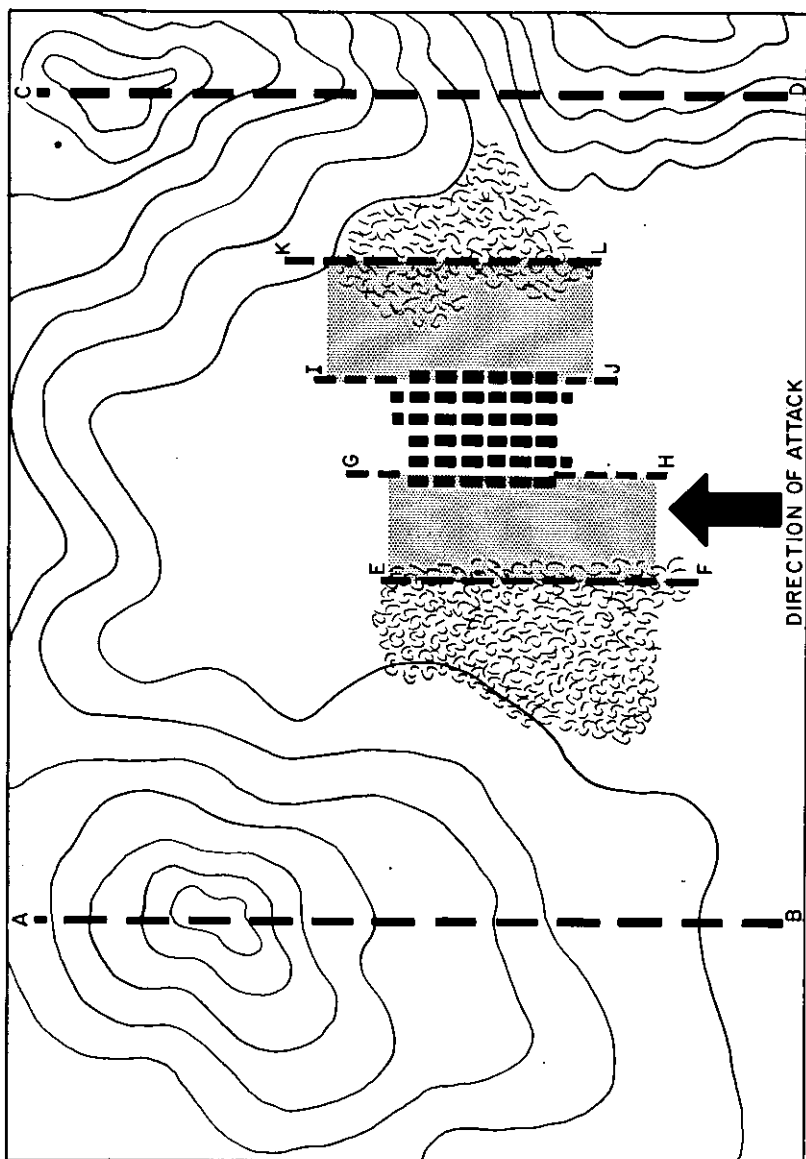


Figure 66. Complex compartment.

the valley. The best axis of advance is the one that offers the most favorable conditions of observation, cross-country movement, fields of fire, concealment, and cover. Often the most favorable route is along the slopes of a ridge below the military crest rather than along the valley floor. A valley approach should never be used when the enemy controls dominant flank observation into the valley, where there are numerous obstacles, and the soils have poor trafficability characteristics.

- (2) The suitability of a ridge for an avenue of approach depends upon its width and shape, the size and frontage of the unit concerned, the distance to adjacent ridges and their elevations, and the capabilities of the enemy weapons. A ridge approach places the axis of advance along dominant observation, but offers little protection from enemy fire directed at the ridge. Usually the best axis of advance in a ridge approach is slightly below the topographical crest, with sufficient forces deployed to control the crest.
- (3) Cross compartments provide the defender with the most favorable terrain for obtaining maximum observation and fields of fire. Mutual support between units, both laterally and in depth, is available and fires may be massed on almost any point that is threatened by the attacking forces. Cross compartments also provide the defender with successive defensive or delaying positions. The concealment or cover provided by each limiting feature permits the defender to shift his reserves to meet or counter threats to his position.

Section II. SPECIAL OPERATIONS

135. Amphibious Operations

a. General. Amphibious operations require detailed studies of hydrography, weather, and terrain. A discussion of the requirements and preparation of these studies is beyond the scope of this manual. They are covered in FM's 60-5, 60-10, 60-30, 110-101, and 110-115, which also describe the characteristics, tactics, and techniques of amphibious operations.

b. Weather Effects. All phases of an amphibious operation are directly influenced by weather conditions. The selection of D-day and H-hour, for example, is determined by the effects that the predicted weather will have upon the tides, beaching and unloading conditions, speeds of vessels, air support, and visibility. Adverse weather increases the difficulty of the ship-to-shore movement and reduces the effectiveness of supporting arms. During the approach to the objective area, poor weather conditions may provide cover for the amphib-

ious force, but favorable weather is essential for the actual landing and during the initial buildup that follows. The excessive sea and swell caused by bad weather at that time may end the movement of troops and supplies, ashore, jeopardizing the entire operation.

c. Terrain Effects.

- (1) From a hydrographic viewpoint, the ideal beach for an amphibious landing is one near a strategic location, with no obstructions seaward; deep water close nearshore; a firm bottom; minimum variation in tides, currents, or surf; and gradient of at least 5 percent that is suitable at all times for the beaching and retraction of all types of landing craft and ships under all conditions of load. The beach terrain should be gently rising, relatively clear, with a firm surface that has adequate drainage. Adequate exits from the beach area should be available. Flat or gently rising terrain, backed by a coastal range high enough to mask the landing area is the most desirable for landing operations. These ideal conditions are rarely found, so that suitable areas must be evaluated carefully to determine those that come nearest to the optimum requirements.
- (2) A landing on a wide coastal plain provides unrestricted maneuver room usually free from enemy observation and a subsequent advance from the beach can be made in any direction. Boundaries and objectives are hard to locate on this type of terrain, however, and there are few prominent registration points for artillery, naval gunfire, and aerial bombardment. Usually there is no good defensive terrain on the flanks of the beachhead, so that more troops are required to protect the flanks.
- (3) Terrain which rises evenly to a considerable distance back from the beach gives the defender excellent observation and fields of fire. The beachhead may be secured by advancing far enough inland to prevent enemy field artillery from firing on the landing area. More commonly, the coastal area remains flat for some distance and then rises abruptly to a coastal ridge. The landing force must seize successive inland hill masses on the ridge before the beach is secure from enemy direct-fire weapons or ground-observed artillery fire.
- (4) Ground that is sharply broken by extensive sand dunes or a low coastal plateau, provides the attacker with concealment from enemy observation. The small compartments and corridors limit the range of defensive fires. Direction and control may be extremely difficult, however, and the defender has a series of local delaying positions from which he can slow down the initial seizure of the beachhead.

- (5) Mountains located directly on the sea usually limit the number of beaches large enough to accommodate a landing force of effective size. Where steep ground is lightly defended or neglected by the enemy, a lightly equipped force may seize it and gain surprise. Airborne troops may be used to block the movement of enemy reserves to the landing area, or to secure passes through the mountains and thus prevent the enemy from interfering with the amphibious landing.

136. Airborne Operations

a. General.

- (1) The characteristics, tactics, and techniques of airborne operations are discussed in FM's 57-20 and 57-30.
- (2) Airborne forces are capable of crossing such terrain barriers as inland seas, mountains, and jungles that represent serious obstacles to the movement of other troops. Usually airborne assaults are made on terrain that is relatively undefended, to secure initial surprise.
- (3) Weather has greater restrictive effects upon airborne operations than upon ground operations. Adverse weather may cause postponement or delay in initiating an operation, and prevent adequate reinforcement or supply by air.
- (4) In addition to terrain studies covering landing and drop-zone areas, special studies may be required to determine the most favorable routes for linkup between airborne forces and friendly ground units.

b. Terrain Requirements.

- (1) One of the principal factors influencing the selection of a landing area for airborne forces is the terrain. The area chosen must provide adequate space to permit defense in depth; room for maneuver; a safe landing for troops, supplies, and equipment; and protection for critical installation.
- (2) Airborne troops can land on any terrain that is relatively free from obstacles. Unobstructed areas are required for the landing and recovery of heavy equipment dropped by parachute.
- (3) Assault aircraft can land on any relatively level and unobstructed terrain that has suitable trafficability. Other fixed-wing transport aircraft require suitable airfields or prepared landing strips. Rotary-wing and other aircraft with vertical takeoff and landing characteristics can land in areas that are otherwise accessible only to parachute units.
- (4) The selection of drop areas for the delivery of supplies by parachute requires a consideration of the following terrain characteristics—

- (a) *Length.* The required length of the area depends upon the type of plane being used. Normally an area 500 yards long is a minimum requirement.
- (b) *Width.* A width of 200 yards is minimum. The pilot must have a reasonable amount of room so that he may fly to the right or left of the center of the area, allowing for the drift of his plane under the influence of surface winds.
- (c) *Surface conditions.* The type of soil must be considered in relation to the effect that it will have upon the falling loads. A hard surface may cause the bundles to break open upon landing. Soil that is muddy or swampy may cause the dropped loads to bury themselves upon landing, making recovery difficult or impossible.
- (d) *Topography.* A clear and level area is desirable. Drop zones on a steep slope or mountainside cause the bundles to scatter, tumble, and break open. A mountain or hill top usually has turbulent winds that reduce drop accuracy and make the drift of bundles unpredictable.
- (e) *Access.* A desirable drop zone has an adjacent road, or terrain adjoining the area, that offers good access for vehicles, so that the dropped supplies can be recovered and transported conveniently.

Section III. WATER SUPPLY

137. General

a. An adequate supply of water for drinking, sanitation, and vehicle operation is one of the fundamental needs. In arid and semiarid regions, water supply is the primary factor affecting all plans and operations. Entire campaigns in desert lands may be conducted solely to secure water sources or to deny them to an enemy.

b. All feasible sources and methods for developing them must be considered when making plans for the water supply of troops and installations. Development data are obtained from reconnaissance, map study, reports of runoff and rainfall average, and geological surveys. Water sources are located by a study of maps, aerial photographs, water resources data, and intelligence reports, then verified by field reconnaissance if feasible. Detailed information concerning reconnaissance for water sources is contained in TM 5-295.

138. Sources of Water

a. General.

- (1) Water may be obtained from wells, streams, springs, lakes, and municipal or other supplies that are already developed. Water for permanent and semipermanent installations also

may be secured from the distillation of sea water or the drainage from building roofs.

- (2) Investigations to select a water source must consider the quantity and quality of the water, and the conditions at the proposed sites from which the water supply would be secured.
- (3) Water sources and characteristics, from a geological viewpoint, are discussed in TM 5-545.

b. Quantity.

- (1) Military water requirements and methods for measuring flow are given in TM 5-295.
- (2) The quantity of water available in an area depends chiefly upon the climate. In temperate and tropical regions with less than 25 inches of annual precipitation, most streams become dry in drought periods. Streams usually flow throughout the year in temperate regions with more than 25 inches of annual rainfall and in tropical regions where the rainfall exceeds 35 to 40 inches. Seasonal variations may reduce the flow of water below the required amount or result in water points being flooded by seasonal high water periods.
- (3) Information concerning the seasonal characteristics of water sources should be obtained from local inhabitants. Terrain studies usually indicate alternate water sources for use in case the primary sources dry up, become flooded, or cannot be used because of enemy action.

c. Quality.

- (1) Color, turbidity, odor, taste, mineral content, and contamination determine the quality of water. TM 5-295 gives methods for estimating these characteristics and describes the use of standard test kits.
- (2) The quality of water will vary according to the source and the season and will depend on the kind and amount of bacteria present, and the presence of dissolved matter or sediment. Streams in inhabited regions commonly are polluted, with the sediment greatest during flood stages. Streams fed by lakes and springs, with a uniform flow, are usually clear and vary less in the quality of water than do those fed mainly by surface runoff. Water in large lakes generally is of excellent quality, the purity increasing with the distance from shore. Very shallow lakes and small ponds are usually polluted.

d. Site Requirements.

- (1) The ease with which a water source can be developed, operated, and maintained is determined largely by the location of the source and the available routes of communication. The design of the collecting system and the difficulties of

development, operations, and maintenance are partially influenced by site conditions, topography, soils, and vegetation.

- (2) Water sources should permit convenient access by users. A military water point should be located as close as possible to a main route without interfering with traffic. There should be an all-weather access road leading to the place of storage, with a turnaround or separate exit, and an all-weather off-road parking area for trucks waiting to be filled. In locating the water point, attention is given to concealment and cover, possible nearby targets which may attract enemy fire, drainage, road connections, condition of the banks and the bed if surface water is being drawn, and the means required to develop the source.
- (3) Wherever possible, existing water supply systems are used. These must be carefully checked by engineers and medical authorities. Purification units may have to be installed. The possibility of contamination by enemy agents also must be considered.

139. Surface Water

a. General.

- (1) Surface water sources are generally more accessible and adequate in plains and plateaus than in mountains.
- (2) Large amounts of good quality water normally can be obtained in coastal, valley, or alluvial plains and in glacial plains and plateaus. While large quantities also can be secured in delta plains, the water may be brackish or salty. Supplies of water are scarce and difficult to obtain on lacustrine, loess, volcanic, and karst plains and plateaus, where streams are few or nonexistent.
- (3) In the plains and plateaus of arid regions, water usually cannot be obtained in the quantities required by a modern army. Much of the water that is available is highly mineralized.
- (4) In the plains and plateaus of humid tropical regions, surface water is abundant, but it is generally polluted by bacteria and requires treatment.
- (5) Perennial surface water supplies are difficult to obtain in Arctic regions. In summer, water is abundant but often polluted. In winter it can be obtained from beneath the ice in the larger lakes and streams, but its quality is poor because of a high organic content.

b. Springs and Seeps.

- (1) There are two types of springs or seeps: those originating at the base of steep slopes where the topography breaks abruptly, and those caused by faulting. The first type usually is found along the edges of a valley, and is characterized by perennial flow and fresh, cold water. The second type is caused by the fracture or displacement of confining clay or rock layers above an artesian water-bearing formation (aquifer), thus forcing the water in the artesian zone to the surface. Springs of this type often are thermal, and may contain excessive amounts of minerals. Frequently the depth of a source of water can be estimated by the temperature of the water—the hotter the water, the deeper the source.
- (2) Spring water is generally clear, cool, and low in organic impurities. It may be hard because of a high dissolved mineral content. In regions where seasonal rainfall varies greatly, the spring flow often decreases during long periods of dry weather. The heavy infiltration of surface water causes some springs to become turbid, and may produce contamination.

c. Streams. Streams are the most common source of surface water supply. Streamflow may vary with precipitation, temperature, and the amount of vegetation. Turbidity and mineral content vary with the flow and with watershed conditions. Since large flows produce high dilution, many such streams may be suitable sources of water supply although they receive raw or partially treated sewage. However, water from such streams must be settled, filtered, and chlorinated before use.

d. Lakes. Ordinarily, lakes are a satisfactory source of water supply. The water level and average yield in small lakes may vary. Many lakes receive sewage flow, have a high content of dissolved minerals, and may have considerable vegetative growth or contain vegetable or animal organisms. These can usually be removed by purification processes.

e. Wells.

- (1) Water from wells usually is clear, cool, and low in organic impurity, but it may be high in dissolved mineral content.
- (2) Wells may be either shallow or deep, depending upon their location on the aquifer. They may be free-flowing or require pumping. In regions having considerable variation in seasonal rainfall, shallow wells are affected by the height of the water table, which may be lowered by excessive withdrawal or prolonged drought. In wells near the seacoast, excessive withdrawal of fresh water may lower the water table, allowing infiltration of salt water which ruins the well and the

surrounding aquifer. Information about wells and well drilling is contained in TM 5-297.

- (3) Because it is difficult to locate ground-water sources suitable for development, the assistance of a geologist and, if possible, a local well-driller should be obtained. Other sources of information are geological ground-water reports and terrain studies issued by higher headquarters.
- (4) The water yield of wells is measured by methods described in TM 5-297. To estimate the possible yield of proposed wells, information is sought about existing wells that tap similar water-bearing formations in the vicinity.
- (5) Both large- and small-diameter wells are used for military installations. Large-diameter wells usually are dug by hand, in diameters up to 50 feet. They may be used as reservoirs, the water level falling during periods of withdrawal and being replenished from subterranean flow during periods of light demand. Small-diameter wells, normally made by driving, jetting, boring, or drilling, do not provide storage.
- (6) Deep wells are drilled by percussion rigs or rotary equipment. The amount of water obtained from deep wells will depend upon local conditions. They are less subject than shallow wells to seasonal fluctuation, contamination, and pollution.

140. Ground Water

a. Ground water is obtained without difficulty from unconsolidated or poorly consolidated materials in alluvial valleys and plains, streams and coastal terraces, alluvial fans, glacial outwash plains, and alluvial basins in mountainous regions. Areas of sedimentary and permeable igneous rocks also may have fair to excellent aquifers, although they do not usually provide as much ground water as areas composed of unconsolidated materials. Aquifers of this type underlie coastal plains, inland sedimentary plains and basins, karst and volcanic plains and plateaus.

b. Large amounts of good-quality ground water may be obtained at shallow depths from the alluvial plains of valleys and coasts, and in somewhat greater depths in their terraces. Large quantities may also be secured from shallow wells in delta plains, although it is apt to be brackish or salty.

c. Aquifers underlying the surface of inland sedimentary plains and basins also provide adequate amounts of water. Often these formations lie within a few hundred feet of the surface. Those at greater depths yield very hard water which may be too highly mineralized to be drinkable.

d. Abundant quantities of good-quality water generally can be obtained from shallow to deep wells in glacial plains and plateaus. In

loess plains and plateaus, small amounts of water may be secured from shallow wells, but these supplies are apt to fluctuate seasonally.

e. Large springs are the best sources of water in karst plains and plateaus. Wells may produce large amounts if they tap underground streams. The siting and drilling of wells is difficult because the areas of permeability and the solution cavities in limestone cannot be easily predicted.

f. Shallow wells in low-lying lava plains normally produce large quantities of ground water. In lava plateaus, where water is more difficult to find and wells are harder to develop, careful prospecting is necessary to obtain adequate supplies. Springs and wells near the base of volcanic cones may yield fair quantities of water, but elsewhere in volcanic cones the ground water is too far below the surface for drilling to be practicable.

g. Plains and plateaus in arid climates generally yield small, highly mineralized quantities of ground water. In semiarid climates, following a severe drought, there frequently is a flow of subsurface water under an apparently dry streambed that may yield considerable amounts of excellent water. Ground water is abundant in the plains and plateaus of humid tropical regions, but usually it is polluted by bacteria. In Arctic and subarctic plains and plateaus, wells and springs fed by ground water above the permafrost are dependable only in summer; some of the sources freeze in winter, and subterranean channels and outlets may shift in location during the seasons. Wells that penetrate aquifers within or below the permafrost, however, are good sources of perennial supply.

h. Adequate supplies of ground water are hard to obtain in hills and mountains composed of gneiss, granite, and granitelike rocks. They may contain springs and shallow wells that will yield water in small amounts.

141. Water Supply Systems

a. There are three basic types of water supply and distribution systems—

- (1) *Gravity.* The storage reservoirs of gravity distribution systems usually are located high enough to develop the required pressure and flow. Sometimes the storage tanks are filled by gravity from springs located at a higher level, but ordinarily they are filled by pumps.
- (2) *Direct pumping.* In direct pumping systems, ordinarily there are no elevated storage tanks. The water is pumped into the distribution system from ground storage reservoirs or wells at a rate depending on demand.
- (3) *Combination.* Primary mains are supplied by both gravity and direct pumping in combination systems.

- b. The essential parts of a water supply system are—
- (1) *Headworks*, usually a reservoir formed by a dam.
 - (2) *Conduit*, sometimes an open canal or an aqueduct, but more commonly made of wood, iron, or steel that is watertight to prevent contamination and losses by evaporation, absorption, and changes in temperature.
 - (3) *Distributing system*, which connects with the plumbing in buildings. Large *mains* carry the water from the source to *service pipes*, which take it to individual buildings and other outlets.

142. Information Requirements

Special water supply studies are made by engineers, assisted by geologists and hydrologists. The information required in terrain intelligence studies should include the following—

a. *General.*

- (1) Normal level of water table and variations.
- (2) Yield of springs and wells, and variations.
- (3) Potability and contaminations.
- (4) Underground flow in dry watercourses.

b. *Surface Supplies.*

- (1) Total drainage area.
- (2) Rainfall and runoff data.
- (3) Sources and kinds of possible contamination, including sewage or industrial wastes.
- (4) Chemical and bacteriological analyses.

c. *Wells.*

- (1) Rainfall data.
- (2) Reports of available well logs and test data.
- (3) Physical, chemical, and bacteriological analyses.

d. *Existing Water Supply System.*

- (1) Source of supply.
- (2) Quantity provided; ultimate capacity.
- (3) Treatment methods.
- (4) Distance from supply to proposed military user point.
- (5) Pressures.
- (6) Chemical and bacteriological analyses.

APPENDIX I

REFERENCES

1. Field Manuals (FM)

FM 3-5	Tactics and techniques of chemical, biological and radiological (CBR) warfare.
FM 5-15	Field fortifications.
FM 5-20	Camouflage, basic principles and field camouflage.
FM 5-22	Camouflage materials.
FM 5-30	Engineer intelligence.
FM 5-36	Route reconnaissance and classification.
FM 21-26	Map reading.
FM 21-30	Military symbols.
FM 21-40	Small unit procedures in atomic, biological, and chemical warfare.
FM 30-5	Combat intelligence.
FM 30-7	Combat intelligence battle group, combat command, and smaller units.
FM 30-15	Examination of personnel and documents.
FM 30-16	Technical intelligence (U).
FM 31-10	Barriers and denial operations.
FM 31-25	Desert operations.
FM 31-50	Combat in fortified areas and towns.
FM 31-60	River-crossing operations.
FM 31-70	Basic cold weather manual.
FM 31-71	Northern operations.
FM 55-8	Transportation intelligence.
FM 55-26	Transportation inland waterways service.
FM 55-31	Highway transportation service in theaters of operations.
FM 55-51	Transportation terminal commands theater of operations.
FM 57-20	Airborne techniques for divisional units.
FM 57-30	Airborne operations.
FM 60-5	Amphibious operations battalion in assault landings.
FM 60-10	Amphibious operations; regiment in assault landings (U).

FM 60-30-----	Amphibious operations; embarkation and ship loading (unit loading officer).
FM 72-20-----	Jungle operations.
FM 100-5-----	Field service regulations; operations.
FM 100-15-----	Field service regulations; larger units.
FM 101-5-----	Staff officers' field manual; staff organization and procedure.
FM 101-10-----	Staff officers' field manual: Organization, technical, and logistical data.
FM 101-31-----	Staff officers' field manual: Atomic weapons employment (U).
FM 110-101-----	Intelligence: Joint landing force manual.
FM 110-115-----	Amphibious reconnaissance.

2. Technical Manuals (TM)

TM 3-240-----	Field behavior of chemical agents.
TM 5-248-----	Foreign maps.
TM 5-249-----	Terrain models and relief map making.
TM 5-250-----	Roads and airfields.
TM 5-260-----	Principles of bridging.
TM 5-295-----	Military water supply.
TM 5-297-----	Wells.
TM 5-350-----	Military pipeline systems.
TM 5-541-----	Control of soils in military construction.
TM 5-545-----	Geology and its military applications.
TM 6-242-----	Meteorology for artillery.
TM 23-200-----	Capabilities of atomic weapons (U).
TM 30-210-----	Interrogation procedures (U).
TM 30-245-----	Photographic Interpretation handbook.
TM 30-246-----	Tactical interpretation of air photos.

3. Textbooks

Geology: Principles and Processes. Emmons, Thiel, Stauffer, and Allison. McGraw-Hill Book Co., New York.

Physical Elements of Geography. Finch and Trewartha. McGraw-Hill Book Co., New York.

Human Geography. White and Renner. Appleton-Century-Crofts, Inc., New York.

APPENDIX II

CHECKLIST FOR TERRAIN STUDIES

1. Purpose and Limiting Considerations

2. General Description of the Terrain

- a. Synopsis
- b. Climatic conditions
 - 1. Temperatures
 - 2. Precipitation
 - 3. Winds
 - 4. Visibility
 - 5. Cloudiness
 - 6. Humidity
 - 7. Electrical disturbances (where applicable)
- c. Topography
 - 1. Relief and drainage systems
 - 2. Vegetation
 - 3. Surface materials
 - 4. Manmade features
 - 5. Special features
- d. Coastal hydrography (where applicable)
 - 1. Sea approaches
 - 2. Beaches
 - 3. Tides and currents
 - 4. Sea and surf

3. Military Aspects of the Terrain

- a. Tactical aspects of the terrain
 - 1. Observation
 - 2. Fields of fire
 - 3. Concealment
 - 4. Cover
 - 5. Obstacles
 - 6. Movement
 - 7. Key terrain features
 - 8. Avenues of approach
- b. Engineering aspects of the terrain
 - 1. Construction sites
 - 2. Construction materials
 - 3. Water supply

4. Maps and Charts

- a. Topographic map(s)
- b. Trafficability map(s)
- c. Cross-country movement map(s)
- d. Movement map(s)
- e. Landing map(s) (where applicable)
- f. Special map(s) (where applicable)
 - 1. Geological maps
 - 2. Soils maps
 - 3. Hydrographic charts
 - 4. Town plans
 - 5. Road maps

APPENDIX III

OUTLINE FOR TERRAIN STUDIES

1. Purpose and Limiting Considerations

State the purpose and limiting considerations under which the study is being prepared. This statement should include the scope of the study in area, time, and subject matter, and any information on the tactical situation, mission, or method of operations that is pertinent to the study.

2. General Description of the Terrain

a. Synopsis. State briefly the impact of the terrain on military operations.

b. Climatic Conditions. Describe predicted meteorological conditions for the period, based on climatic data. Present climatic data graphically whenever possible. The requirements of the study will determine the exact information presented and the manner of presentation.

- (1) *Temperature.* Climatic data—give frequency of occurrence of temperatures during period.
- (2) *Precipitation.* Climatic data—state frequency of occurrence of precipitation by type and amount.
- (3) *Winds.* Climatic data—give frequency of occurrence of winds of certain velocities and direction. Use wind rose.
- (4) *Visibility.* Present graphically data on times of sunrise, sunset, twilight, moonrise, and moonset. Describe effect of fogs, mist, haze, and other influences on visibility. State expected visibility by distance when applicable.
- (5) *Cloudiness.* Describe when applicable and separate from precipitation and visibility. Climatic data—give data of frequency of occurrence and time of occurrence of various cloud conditions.
- (6) *Humidity.* Describe only when significant. Describe effect when combined with other weather elements, such as oppressive heat or wind chill.
- (7) *Electrical disturbances.* Describe only when significant.

c. Topography. If pertinent, describe the following characteristics by written or graphic means. Recommend the use of a topographic map overprint to emphasize particular characteristics.

- (1) *Relief and drainage systems.* Use ridge and stream lining, contour emphasis, hilltopping, or relief shading to outline the ridge and valley systems. Use numbers, words, or standard symbols to indicate critical relief or drainage conditions.
- (2) *Vegetation.* Indicate location, type and size of trees, density of planting, existence of undergrowth, and the location, type, and density of other significant vegetation.
- (3) *Surface materials.* Indicate the type and distribution of soils, subsoils, and bare rock in the area. Indicate their trafficability under various weather conditions.
- (4) *Manmade features.* Describe fully the significant manmade features. Include roads, railroads, bridges, tunnels, towns, important buildings, fortifications, or airfields when pertinent.
- (5) *Special features.* Describe significant special features such as earthquake zones or active volcanoes.

d. Coastal hydrography. Describe when applicable. Use graphic means whenever possible.

- (1) *Sea approaches.* Describe nature of approaches, bottom conditions, obstacles, gradients, and coastal structures. Use landing-area map to present information graphically.
- (2) *Beach.* Describe dimensions, trafficability, and beach exits. Use landing-area map to present information graphically.
- (3) *Tides and currents.* Describe expected time of occurrence and stage of tides. Present graphically. Describe currents by direction, velocity, and durations.
- (4) *Sea and surf.* Describe height of sea. Describe type of surf, width of surf band, height of surf, and expected duration.

3. Military Aspects of the Terrain

From an analysis of the factors of climate, topography, and coastal hydrography, determine the following military aspects and describe them by written or graphic means. Use of an overlay to the basic topographic map is recommended.

a. Tactical aspects of the terrain. The following aspects are those basic to all tactical operations.

- (1) *Observation.* Determine the effect of the terrain factors on observation from the ground, from the air, and by means of electric or sonic devices when applicable.
- (2) *Fields of fire.* Determine the effect of the terrain factors on the ability of flat- and high-trajectory weapons to deliver projectiles to a target. Consider nuclear weapons when applicable.
- (3) *Concealment.* Determine the capability of the terrain to provide concealment for men, equipment, and installations.

Consider the effect of terrain on concealment by artificial means.

- (4) *Cover*. Determine the capability of the terrain to provide cover for men, equipment, and installations. Consider the problem of cover from flat-trajectory, high-trajectory, and nuclear weapons when applicable.
- (5) *Obstacles*. Determine the capability of the terrain to delay the advance of military forces or impede military operations. Consider both natural and manmade obstacles.
- (6) *Movement*. From an analysis of soils trafficability, natural and manmade obstacles, and existing routes of movement, determine the ability of troops and equipment to move through an area. Use standard color code to describe movement conditions. Use specific terms of movement whenever possible; i.e.—vehicular, cross-country, and foot.
- (7) *Key terrain features*. From an analysis of the terrain and of friendly and enemy methods of operations, indicate those terrain features which appear to be critical, such as a dominant height, a highway, a communication center, or an airfield.
- (8) *Avenues of approach*. From an analysis of all terrain factors affecting capabilities to move men and materiel, determine the avenues of approach to the objective. Consider existing routes of movement, possibilities of cross-country movement, and amphibious or airborne operations when applicable.

b. Engineering aspects of the terrain. Determination of the following military aspects is essential to planning the engineer phase of operations. Include these items in the terrain study when applicable. Describe these aspects in written or graphic form as overprints or overlays.

- (1) *Construction sites*. From an analysis of surface material and other terrain factors, determine areas suitable for construction of roads, airfields, buildings, underground installations, surface defensive installations, or others.
- (2) *Construction materials*. From an analysis of surface materials and other terrain factors, determine the probable location of rock, gravel, sand or other natural construction material.
- (3) *Water supply*. From an analysis of the drainage system and subsurface formations, determine the probable location of potable water and water suitable for construction use.

APPENDIX IV

SAMPLE TERRAIN STUDY

Headquarters 15th Army
Western Germany
January 1945

1. Purpose and Limiting Considerations

a. Purpose. This terrain study considers the area to the south and west of COLOGNE, Germany, for February and March. General boundaries for the zone are the towns of JULICH on the ROER RIVER (3145) and ZULPICH (3418), and the RHINE RIVER north and south of COLOGNE as shown on inclosure 1 (fig. 65). Elements of Fifteenth Army, consisting of armored and infantry units, are located west of the ROER RIVER and presumably will operate in the area with the general mission of advancing north-eastward to the RHINE RIVER.

b. Limiting Considerations. Information presented is based on data obtained from maps, intelligence documents, climatic study, and interrogation. Ground reconnaissance has not been made, nor have the effects of conventional bombing or nuclear action been considered.

2. General Description of the Terrain

a. Synopsis. The area during this period of the year provides favorable conditions for military operations. It is a highly populated mixed farm and industrial region. Construction sites and materials are available and the communication system is excellent. Movement across the RHINE RIVER is canalized at BONN and COLOGNE. Obstacles are the ROER and ERFT RIVERS and the VILLE RIDGE. Conditions influencing movement are sensitive to precipitation.

b. Climatic Conditions. See inclosures 2, 3, and 4 (figs. 68 and 69).

- (1) *Temperatures* will present problems to the effective operation of troops in the field. Inclosures 2, 3, and 4 give compiled temperature data.
- (2) *Precipitation* in some form normally occurs every second day. Wet soils are common. Snowfalls ordinarily do not exceed 6 to 7 inches. Ice, if present, is thin and will not support a man.

- (3) *Wind* direction and velocity are given by the wind roses in inclosures 3 and 4. Winds from the east are usually accompanied by severe temperature drops.
- (4) *Visibility* factors are listed in inclosures 2, 3, 4, and 5 (fig. 70). Fog occurs rarely at this time of year, despite the high relative humidity. The high frequency of moderate to fresh winds favors the formation of low clouds rather than fog.

c. *Topography.*

- (1) *Relief* is low and gently rolling with only two exceptions: the southwestern portion of the map (HOHE VENN) has steep wooded hills and highlands dissected by deep valleys; and a low hilly ridge, hereafter known as the VILLE RIDGE, between the ERFT RIVER and the RHINE RIVER. This area is discussed in detail on the back of the map and later in this study.
- (2) *Drainage.* Streams cross the region generally from southeast to northwest. The ROER RIVER is approximately 80 feet wide, with no fords, and *can be flooded by release of water impounded in dams to the south.* The ERFT RIVER, or canal, meanders through several channels in its flood plain. These channels average 20 to 30 feet in width and 2 to 5 feet in depth. In many places, the river channels are flanked by marshy flats which are drained through numerous deep ditches.
- (3) *Vegetation.* The area is largely devoted to agriculture and pasture but scattered forests do exist, and these are delineated on the map with notes as to density, type, and approximate boll size. Trails and unimproved roads allow restricted passage even through the dense forests. At this period of the year, the ground will be fallow or in low cover crop which will increase its trafficability. Trees are scattered throughout the numerous mine pits in the area.
- (4) *Surface materials.* The region is generally covered by a loamy soil tending toward sandy soil in the south. In the VILLE RIDGE area, the original soils have been stripped off during mining, exposing sand stone and shale. Stream valleys are composed of fine grained silts in the northern reaches and changes to sandy material upstream to the south. The soil immediately west of the RHINE RIVER is composed of sandy well-drained material. Surface materials are discussed further on the back of the movement map.
- (5) *Manmade features.* The manmade features studied include roads, railways, bridges, airfields, towns, and strip mines.
 - (a) An excellent network of roads exists. Only the primary system, that with a route classification of or better, is

shown on the map. In addition, secondary roads of general route classification connect many of the villages. Free egress from roads for cross-country movement is possible in most places.

- (b) Rail communication, as shown on the map, is very good. As a supplement to the standard-gage system, considerable narrow-gage lines exist, particularly in the VILLE RIDGE region. Marshalling yards are located at DUREN, BONN, and COLOGNE. The tunnel on the double-tracked route between DUREN and COLOGNE is a vulnerable point, but may be bypassed through alternate routes.
- (c) The classification of bridges along the primary-road system is 65. Important bridges are indicated on the map with the classification noted if lower than the general class. Bridges on the secondary-road system have a general classification of 55.
- (d) This area contains several large municipal airfields capable of handling heavy-cargo aircraft. These have been marked on the map. Also shown are three landing strips which can be used by assault aircraft. Sections of primary roads and autobahns may be utilized for light Army aircraft strips.
- (e) Most urban areas are well built-up with stone and masonry buildings. Streets, except for boulevards or freeways, are narrow, and may permit only one-way traffic to trucks and tanks. All but the larger cities may be bypassed easily.

3. Military Aspects of the Terrain.

a. Tactical Aspects.

- (1) *Observation.* Observation throughout the area is generally good, although there are small areas of defilade. The VILLE RIDGE affords excellent observation of the lowlands to the east and west. The HOHE VENN area provides good points for observation of the ROER RIVER valley. Small hills afford tactical observation in the plains section. Aerial observation will be excellent, except where woods obscure the ground.
- (2) *Fields of fire.* The area provides generally good fields of fire for all weapons with two exceptions. The broken terrain of the VILLE RIDGE and the HOHE VENN limits fields of fire for flat-trajectory weapons within the ridge masses themselves. However, flat-trajectory weapons situated on

these ridges can command their lowland approaches very effectively.

- (3) *Cover.* Principal cover is offered by the stone structures that make up the cities and farm communities. In the VILLE RIDGE area, some cover can be found in the mine tunnels.
- (4) *Concealment.* The mixed forested areas give good concealment from both air and ground observation. The broadleaf forests are bare of leaves during February and March and offer only limited concealment. Farming practices in this part of Germany are such that little concealment is possible in the winter cover crops, but the many farm buildings and small villages afford good concealment for small units.
- (5) *Obstacles.*
 - (a) The ROER RIVER under normal conditions will offer only minor problems to an assault crossing. Opening or destroying the ROER DAM will flood the ROER VALLEY. If this is done, it will take at least a week for the ROER RIVER to recede, and 2 to 3 weeks for soils trafficability to return to normal.
 - (b) The ERFT VALLEY, with its drained swamps and many canals, will restrict movement to roads in most areas. The river channels themselves are not a serious obstacle to infantry; however, a long thaw, which is quite possible in March, or an unseasonal rain can make them unfordable to foot troops.
 - (c) Wooded areas may restrict vehicular movement to narrow unimproved roads but are passable for infantry under normal conditions.
 - (d) The VILLE RIDGE forms an obstacle of major importance to vehicular and foot movement. It may be easily defended against a superior force, affording the defender excellent observation and concealment in its woods and extensive mine workings.
- (6) *Movement.* This is indicated on the movement map (fig. 67). The area as a whole provides very good movement during dry weather, and fair to doubtful movement during periods of heavy precipitation.
- (7) *Key terrain features.*
 - (a) The VILLE RIDGE dominates the lowlands to the east and west of the hill mass. Routes crossing the VILLE RIDGE are restricted to the roads because of the extensive pits, quarries, and spoil heaps left by coal-mining operations.
 - (b) The HOHE VENN highlands southwest of DUREN overlook the adjacent ROER RIVER valley. In this region

heavy forests and steep slopes restrict vehicular traffic to the roads.

- (8) *Avenues of approach.* The main highways from the ROER RIVER toward COLOGNE offer good avenues of approach from the southwest, and represent the best routes for breaching the VILLE RIDGE. The *best* avenues of approach would be to the north of JULICH-COLOGNE highway where the VILLE RIDGE may be flanked and cut off. The secondary road and rail net is adequate for support of an armored attack. The VILLE RIDGE may be flanked from the south in the vicinity of BONN, but here armored operations will be somewhat restricted and canalized by dense forests, and by the constriction of the corridor between the VILLE RIDGE and the RHINE RIVER.

b. Engineering Aspects of the Terrain.

- (1) *Construction sites.* With the exception of the mining dumps, the southwestern highlands, and the river flood plains, the area is well suited for the construction of roads, airfields, cantonments, depots, and other military surface structures. The land is level and open, the communication net is excellent, and the soil has good stability and bearing capacity. The HOHE VENN highland is better suited for underground facilities than the plains area. Solid sandstone layers are useful as floors and roofs here, and ground water will not be as troublesome as in the flatlands.
- (2) *Construction materials.*
- (a) *Natural materials.* Quarries and gravel banks are available for stone and aggregate at many places. The terraces along the RHINE and ROER RIVERS are good sources of gravel and sand, while sandstone suitable for construction purposes can be quarried west of ZULPICH. Broken rock consisting of sandstone, shale, and soil is piled in the VILLE RIDGE dumps, and west of DUREN. Forests supply adequate quantities of standing timber to cover any foreseeable needs. Small local sawmills may be useful in cutting the timber for use.
- (b) *Manufactured materials.* The heavy industrial buildings in the VILLE RIDGE and COLOGNE areas are good sources of construction steel, lumber, and similar materials needed by engineers. In addition, a large network of mine railroads exists throughout the pits and may be utilized for material.
- (3) *Water supply.* An adequate field water supply may be obtained from the streams and wells of the area. Civilian water supply on farms is obtained from wells, and in cities

through municipal distribution plants and systems which draw water from the major rivers. Emergency water supplies may be drawn from these sources.

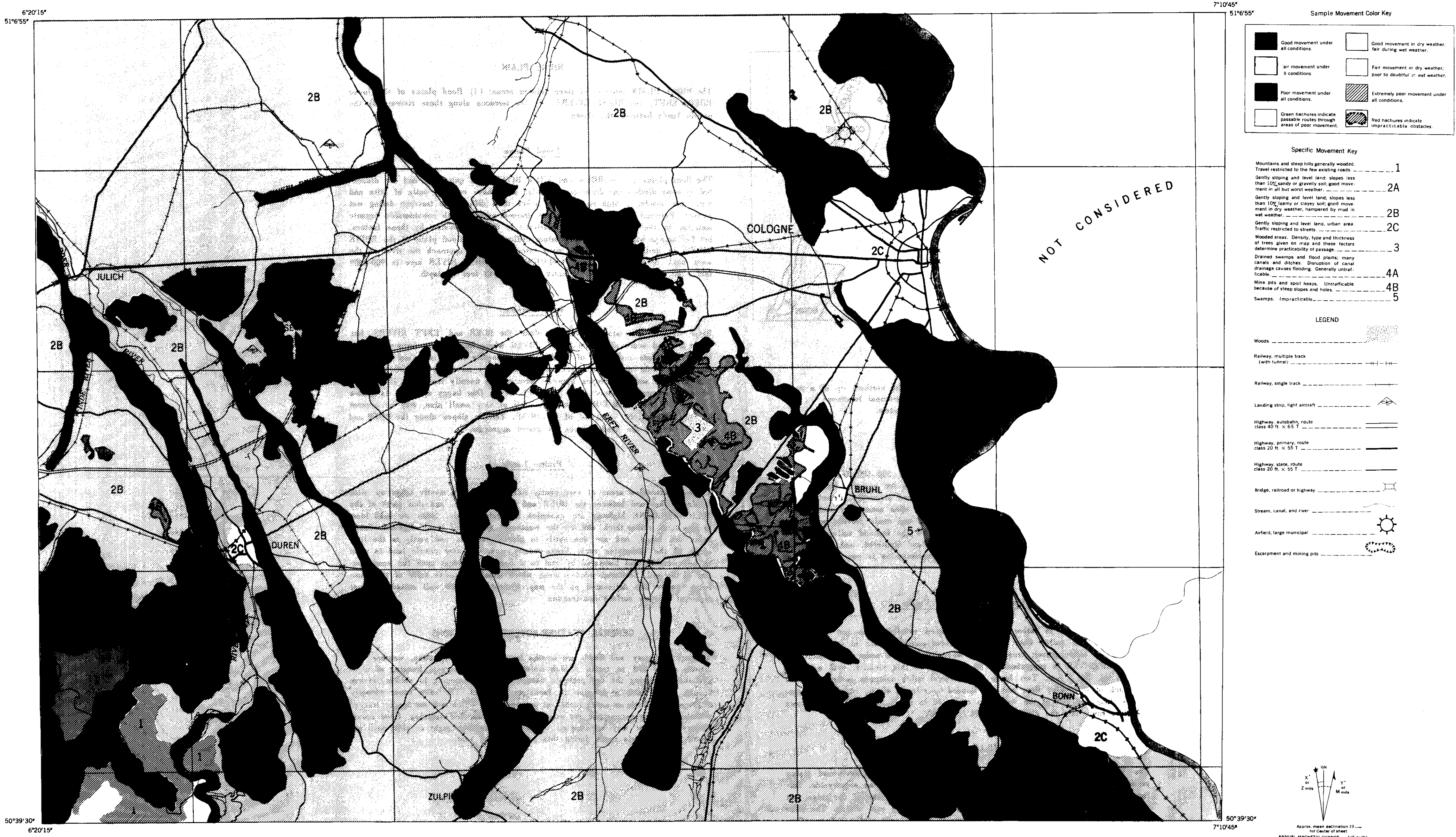
5 Inclosures:

- Inclosure 1. Movement map of Cologne area (fig. 67).
- Inclosure 2. Climatic conditions Cologne, Germany, for February and March.
- Inclosure 3. Climatic data for Cologne area for February (fig. 68).
- Inclosure 4. Climatic data for Cologne area for March (fig. 69).
- Inclosure 5. Ephemeris for Cologne area for February and March (fig. 70).

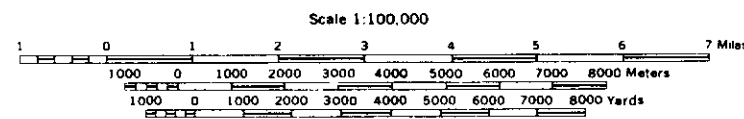
Inclosure 2. Climatic conditions, Cologne, Germany, for February and March

	Feb	Mar
Temperature (° F.):		
Mean maximum.....	43	49
Mean minimum.....	33	37
Absolute maximum.....	66	72
Absolute minimum.....	0	13
Number of days with:		
Minimum—32° F.....	10	6
Maximum—32° F.....	2	0.4
Precipitation (in.):		
Mean.....	1.61	1.73
Maximum.....	4.68	4.06
Minimum.....	0.16	0.28
Maximum in 24 hours.....	1.24	0.81
Mean number of days with:		
Snowfall 0.004 inch.....	6.4	5.9
Snow on ground.....	5.3	2.0
Fog.....	1.2	1.4
Wet soil.....	14.2	13.2
Clear skies.....	3.2	3.1
Partly cloudy skies.....	14.7	19.1
Cloudy skies.....	10.3	8.8
Mean relative humidity (%):		
0700 LST.....	84	82
1400 LST.....	74	67
1900 LST.....	82	76

MOVEMENT MAP COLOGNE AREA



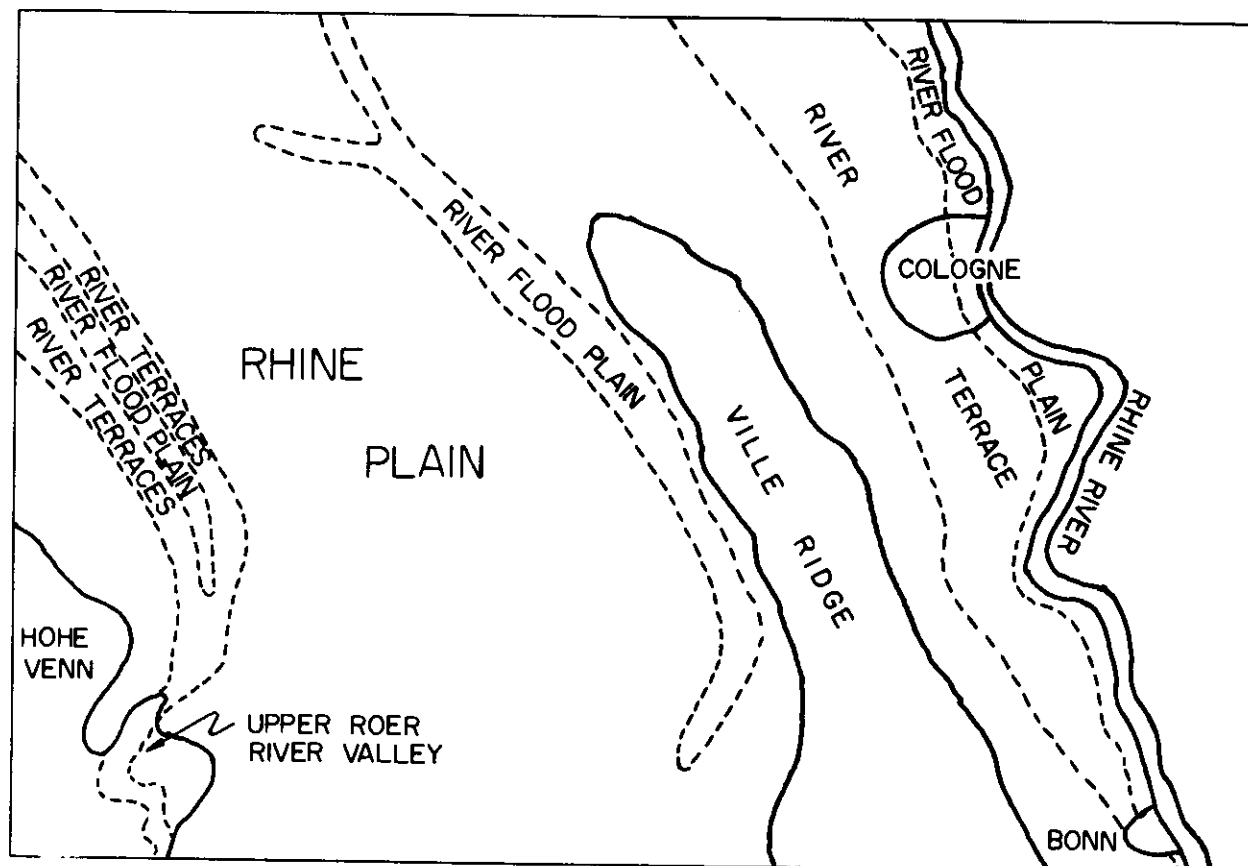
This sample movement map is not to scale



Contour Interval 50 Feet

Prepared by The Engineer School, Fort Belvoir, 1959.
Map keyed to Germany 1:100,000 AMS, S-1 and R-1,
1952, to which reference is made for marginal infor-
mation. Comments concerning field usability are
requested by The Department of Training Publications,
The Engineer School, Fort Belvoir, Virginia. For illus-
trative purposes, bridge classification information has
been purposely omitted from this map. Route classi-
fication information has been added to the legend under
"roads".

Figure 67. Movement Map of Cologne area. (Inclosure 1 to Appendix IV)



HOHE VENN HIGHLAND

The HOHE VENN HIGHLAND shown on the map is the northern tip of a much larger forested plateau to the southwest. It has two principal landforms . . . a dissected upland and the upper ROER RIVER valley system.

Upland

This upland is made up of flattened sandstone hills 300-500 feet high with steep wooded slopes usually above 25 percent. Bluffs are common. Some of the flattened hilltops are open and are used for farming and pasturage. Principal soil type is loam. Cross-country movement is good in the open areas, but steep sandstone-shouldered ravines are frequent barriers. Trails and roads provide occasional passage from the open hilltops through defiles to the lowland valleys. In this area, sandstone may be quarried. Towns are small and scattered, and construction sites for facilities are limited. Road and rail communication is poor as compared to the lowland plains.

Upper ROER RIVER Valley

This valley system is rather narrow with steep wooded sides and occasional escarpments. The valley floor does not exceed one-half mile in width but is made up of sandy gravel; cross-country movement is good under most conditions. The ROER RIVER is approximately 80 feet wide in this vicinity, with a stream velocity of 4-8 ft/sec. Two large dams several miles upstream control its flow and much of the valley floor may be flooded by release of the impounded water. Traffic into and out of the valley is restricted to roads, but a railroad follows the river route into the city of DUREN.

VILLE RIDGE

The VILLE RIDGE is a long (25 miles), narrow (3-5 miles), southward rising promontory with summits 100 to 250 feet above the surrounding countryside. Surface soil type is clay loam with sand loam along the flanks of the ridge, but the overburden is rarely in sight due to extensive surface coal mining. The mine pits, dumps, and spoil heaps, and the great number of industrial buildings effectively limit vehicular movement to roads. Scattered mixed and broadleaf forests are found throughout the ridge and are indicated on the map. Crushed rock is available in the mine dumps. Several coal-driven power generating stations are located here. The ridge area is unfit for airfield sites because of mines, industrial towers, buildings, woods, and so on.

RHINE PLAIN

The RHINE PLAIN consists of three related areas; (1) flood plains of the lower ROER, ERFT, and RHINE RIVERS; (2) the terraces along these rivers; (3) the prairie lands between the rivers.

Flood Plains

The flood plains of the ROER and ERFT RIVERS are quite flat and are dissected by many ditches and drainage channels. They have complex soils of silts and very fine sands; a high water table makes them difficult to traverse during wet periods. Portions of the flood plains are drained swamps with considerable organic material in the soil. Traffic is restricted to the road system by these factors, but foot troops will encounter only minor difficulty. The flood plain of the RHINE RIVER is quite narrow, as the river terraces closely approach the river on the west bank between BONN and COLOGNE. The RHINE RIVER here is 900-1400 feet wide, has a 2-4 ft/sec. velocity and is 20-40 feet in depth.

River Terraces

River terraces are poorly developed along the ROER and ERFT RIVERS, but reach a grand scale along the RHINE RIVER where four or five terraces can be found. They are composed of sandy or occasionally loamy soil, and are up to four miles wide along the west bank. Cross-country movement is good to excellent in most weather. Slopes between terraces are usually less than 10 percent, while the terraces themselves are practically level. One boggy spot (5) is shown between COLOGNE and BONN, but others, all of very small size, may be present on the southwestern outskirts of COLOGNE. Terrace slopes along the ROER and RHINE RIVERS are good sources for gravel aggregate.

Prairie Lands

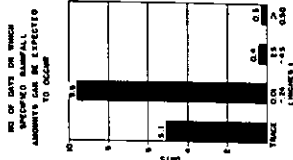
These are extensive areas of very gently rolling topography mostly taken up with farmland. The land between the ROER and ERFT RIVERS, and that north of the JULICH-COLOGNE highway are examples of prairie lands. Soils are sand loam to clay loam, rather thick, and are the weathered product of loess deposits. Sandy areas are found, and are due partly to glacial outwash, and partly to the lithology of the underlying rock. Cross-country movement over prairie land is good in fair weather, but hampered by mud to a degree dependent upon the sand content of the soil. Scattered wooded areas which usually possess soils of the same loamy nature are delineated on the map. Prairie lands are well suited for most types of military surface construction.

GENERAL WEATHER-MOVEMENT RELATIONS

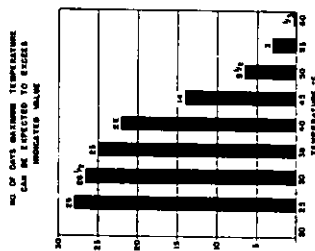
Although February and March are months low in total precipitation, weather conditions cause soil to retain a high moisture content. Alternate freezing at night and thawing during the day prevents normal drainage. Freezing is seldom intense enough or of such a duration to facilitate movement. The snow cover normally does not exceed six or seven inches at any one time, which will not hinder tracked vehicles but may necessitate the use of chains on wheeled vehicles. Good cross-country movement may be counted on for no more than eight or nine days per month in the prairie lands during this period of the year.

CLIMATIC DATA FOR COLOGNE AREA, GERMANY FEBRUARY

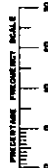
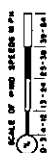
PRECIPITATION



TEMPERATURE

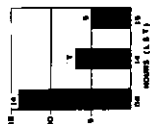


WIND ROSE



TACTICAL AIR SUPPORT

NO. OF DAYS
AT WHICHES POINTS ON
WIND ROSE DIAGRAM
WINDS ARE EXPECTED TO
CEASE AND/OR VIBRATIONS
(+ 0.5 INCHES) ANY/ONE
VIBRATION (0.5 INCHES)



NO. OF DAYS WHEREIN TEMPERATURE
CAN BE EXPECTED TO FALL BELOW
INDICATED VALUE

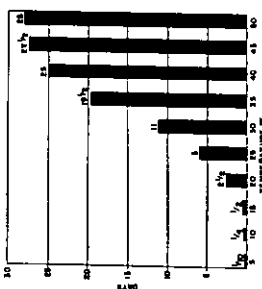


Figure 68. Climatic Data for Cologne Area for February. (Inclosure 3 to Appendix IV.)

CLIMATIC DATA FOR COLOGNE AREA, GERMANY

MARCH

PRECIPITATION TEMPERATURE WIND ROSE TACTICAL
AIR SUPPORT

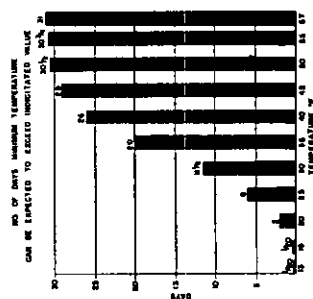
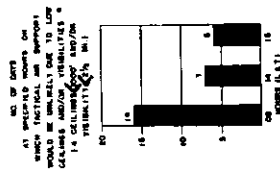
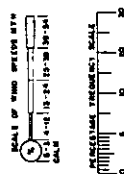
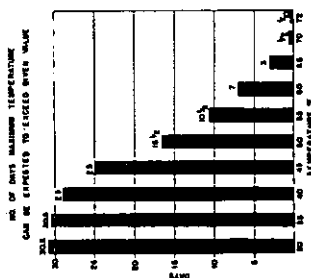
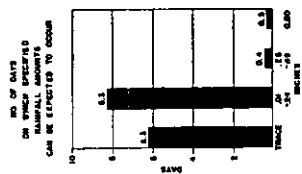


Figure 69. Climatic Data for Cologne Area for March. (Inclosure 4 to Appendix IV.)

EPHEMERIS

COLOGNE, GERMANY 51° N LAT 7° E LONG

FEBRUARY and MARCH 1945

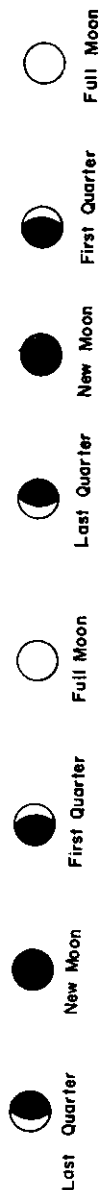
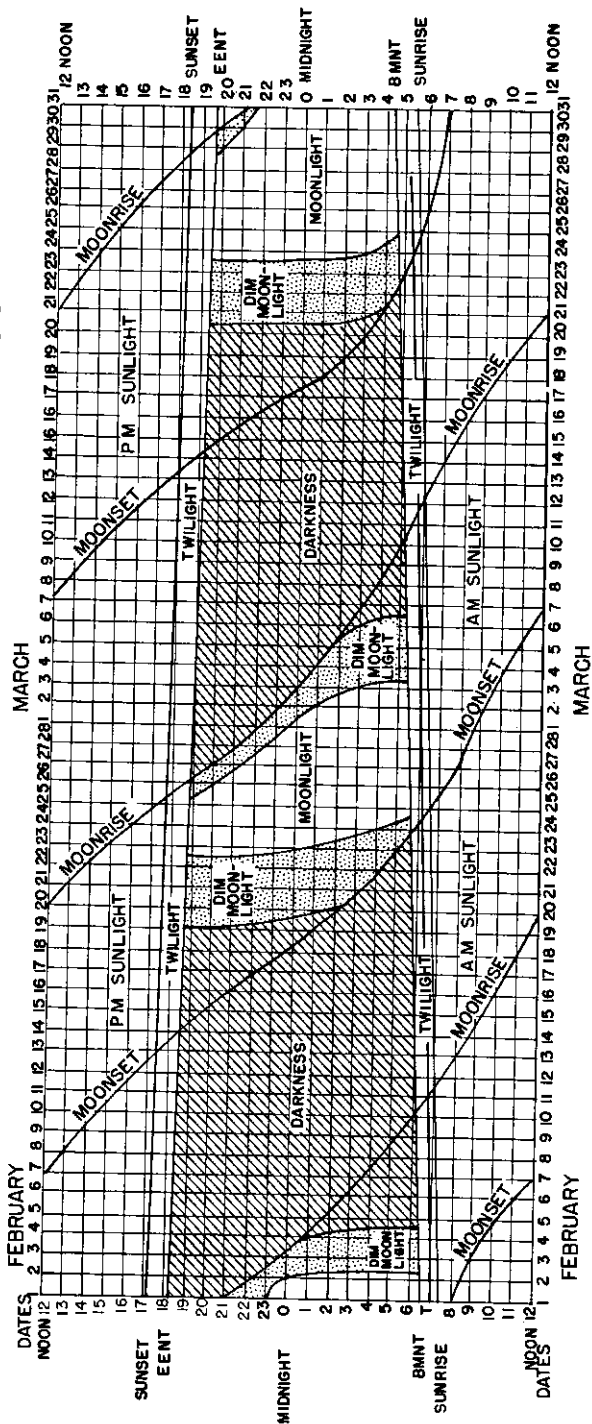


Figure 70. Ephemeris for Cologne Area for February and March. (Inclosure 5 to Appendix IV.)

APPENDIX V

SAMPLE CLIMATIC STUDY

General

This study is divided into four parts, each having a different operational aspect: airborne, amphibious, and overland in two differing climatic regions. *The studies and accompanying data do not refer to any exact geographic locations, but are offered only as a guide for format and content.*

a. Information Sources. Source material for such studies is usually drawn from climatic summaries on file at the Climatic Center, Headquarters Air Weather Service, from NIS sources, and from weather summaries on file at the U.S. Weather Bureau or Congressional Libraries. In the field, information of a climatic nature may be obtained from local Air Weather Service detachments or a national meteorological service office. The climatic study is designed to provide a first estimate of weather factors affecting military operations and should not be regarded as an operational forecast, which normally is applied by other Air Weather Service detachments.

b. Wind Rose. The agency requesting climatic data from Air Weather Service should specify whether the wind speed data is desired in *miles or knots per hour*. The method used to read a *Wind Rose* is shown in figure 71.

Part I

Climatic Factors Affecting an Overland Operation in the Region Surrounding OBJECTIVE ONE During May

In terms of general climate, OBJECTIVE ONE area has a maritime-type climate, characterized by cool, humid winters and mild, comparatively dry summers. The month of May represents a portion of the transition period between these two characteristic seasons.

In the absence of meteorological information for the exact location involved, combined data from adjacent areas, both north and south, were considered to be representative of the climate of OBJECTIVE ONE area and are present as appendix material in tabular and graphical form.

Temperature during May is usually conducive to moderate to strenuous activity. Normally, temperature averages approximately 50° F., with a moderate diurnal and monthly range. Minimum temperatures, especially during the first portion of the month, in valley areas

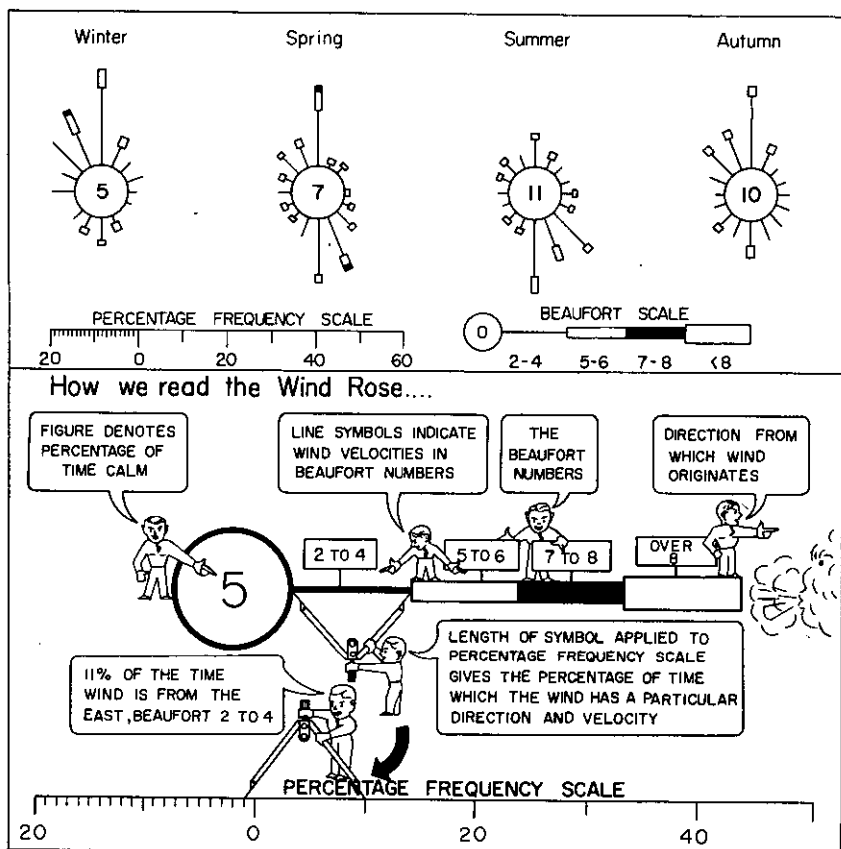


Figure 71. How to read a Wind Rose.

or close to the ground surface are frequently in the mid 30's during early morning hours.

Rainfall is light, averaging 2 to 2½ inches for the month. This amount, well distributed in time (the maximum reported for any 24-hour period is 1½ inches), should not create problems associated with soil moisture and would be sufficient to minimize dust conditions. Snow accumulations on the mountains and passes east of the area melt at this time and provide a source of fresh water for the local streams. Flooding of these streams is unusual.

Relative Humidity is high throughout the day, averaging 80% to 85%. Diurnally, the variation is relatively small, 10% to 20%. Although relative humidities average quite high, the incidence of fog and other forms of restricted visibilities is quite low; about 5% of the time the visibility is less than 2½ miles.

Cloud cover and visibilities are well suited for tactical air support.*

*Minimum ceiling and visibility requirements depend upon the type of support, the equipment involved, and upon the type of terrain over which this support must operate.

Winds are primarily from a westerly direction, southwest through northwest, with an average speed of 7 to 10 knots. Approximately 25% of the time the winds are less than 3 knots.

Table I. Overland Operation OBJECTIVE ONE—May

Temperature (° F.):	
Mean Maximum.....	62
Mean.....	50
Mean Minimum.....	38
Recorded Extremes.....	77 to 31
Mean Number of Days with:	
Fog.....	1
Thunderstorms.....	0
Rain.....	8

Part II

Climatic Factors Affecting an Amphibious Landing on OBJECTIVE TWO During May or June

Complete meteorological observations on the island were made only during a brief period during World War II. Plantation records for longer periods of record have been used in arriving at precipitation estimates. Climatic data are presented as appendix material.

Climatically, OBJECTIVE TWO Island has all the typical tropical characteristics with heavy, shower-type rainfall and a small diurnal and seasonal temperature range. Since the island is affected by the monsoon wind, the May-June period is one of transition, during which winds are normally light and variable.

Temperature conditions are not conducive to human activity, and the daily range of temperatures is insufficient to alleviate this human discomfort at night. The mean temperature is approximately 80° F., with a maximum daily range of about 20 Fahrenheit degrees.

Humidity is constantly high and coupled with the warm temperatures creates problems of material storage and supply, in addition to adding to human discomfort. Mean relative humidity is approximately 80%, with only slight variation diurnally.

Visibility is seldom restricted by weather factors except during brief periods of heavy shower activity; however, dense vegetation limits ground visibility severely unless some form of clearing has taken place.

Precipitation is of the brief, heavy shower-type that usually occurs during the afternoon on an average of 1 out of 2 days. Thunderstorms are quite frequent, with an average of 8 storms per month.

Table I. *Amphibious Operations OBJECTIVE TWO Island—May and June*

Temperature (° F.):	May	June
Mean Maximum.....	88	90
Mean.....	81	82
Mean Minimum.....	75	76
Recorded Extremes.....	93 to 73	95 to 74
Mean Number of Days With:		
Thunderstorms.....	8	6
Precipitation.....	17	12
≤ 0.5 inch.....	12	9
0.6 to 1.9 inches.....	4	2
> 2.0 inches.....	1	1

Although total precipitation is highly variable from year to year, it is more than adequate to keep soils moist, support heavy vegetation, and present vehicular transport problems. Maximum precipitation in 24 hours reported for the island during this period was 7.2 inches during May.

Winds are light and variable, except during heavy showers; however, during June the southeast monsoon is being established and southeast winds become more predominant. In the forested areas, winds are usually very light or calm, but along coastal strips they average about 5 knots. Typhoon winds are not considered a threat to operations this early in the season.

Part III

Climatic Factors Affecting an Airborne Operation in the Vicinity of OBJECTIVE THREE During September

For the purposes of this report, it was assumed that paratroop operations would be carried out only with a ceiling value equal to or greater than 1,000 feet, visibility equal to or greater than 2½ miles, and wind speed less than 13 knots. On this basis, favorable weather occurs most frequently during the midafternoon. Unfavorable conditions increase gradually until early morning hours when adverse weather occurs approximately 25% of the time. Tactical air support, depending upon the type needed and equipment utilized, should be able to operate 70% to 80% of the daylight hours.

Temperatures are not extreme during this period and should not present problems of human comfort. The extreme range of temperature is large, but normal temperatures are quite moderate with a mean maximum of 67° F. and a mean minimum of 50° F.

Precipitation, in the form of drizzle, light rain, or showers, occurs on the average of 2 days out of 3, giving an average September rain-

fall amount of approximately 2½ inches. Heavy rainfall is infrequent, but when it occurs, poorly drained areas become flooded and trafficability problems are intensified.

Fog restricts visibility to less than one-half mile on 1 day of 10, most often during the early morning hours. During the afternoon and early evening the possibility of restricted vision caused by air pollutants is even less.

Winds are most frequently from the southwest, with about 10% of the observations showing wind speeds greater than 13 knots. Diurnal variations in wind strength or direction appear negligible in this particular area.

Table I. Airborne Operation OBJECTIVE THREE—September

Temperature (° F.)	September
Mean Maximum.....	67
Mean.....	58
Mean Minimum.....	50
Recorded Extremes.....	87 to 38
Mean Number of Days With:	
Thunderstorms.....	3
Precipitation.....	19
< 0.1 inch.....	9
0.1 to 0.5 inch.....	6
> 0.5 inch.....	4
Percentage Frequency, by Hour, of Weather Favorable for Paratroop Operations (Ceiling ≥ 1,000 ft., Visibility ≥ 2½ miles, Wind < 13 kt).	
0800 LST 74%	
1400 LST 96%	
1900 LST 91%	

Part IV

Climatic Factors Affecting an Overland Operation in the Vicinity of OBJECTIVE FOUR During February

Climatically, the objective area has a marine climate, which implies mild, cloudy and humid weather.

Temperatures usually are not severe, as a result of the moderating effect of the water on the migratory air masses. However, alternate freezing and thawing of the normally water-soaked soil surface is common, creating problems of vehicular movement due to rapid deterioration of natural surfaces.

Precipitation in the form of rain, drizzle, and/or snow occurs on approximately one-half of the days during the month. Snowfall is usually small in amount, but is apt to be wet, heavy, and clinging; possibly resulting in destruction of overhead wires and some vegetation. Snow cover is usually shortlived, being destroyed by the frequent warmer rains. Soils are usually water soaked; only during exceptionally cold winters does the ground freeze to any depth.

Fog occurs on 4 or 5 days during the month and is usually quite dense, persistent, and widespread, restricting visibility to several hundred yards and precluding any tactical air support. Cloud cover is usually present, but normally the effective ceiling is about 2,000 feet.

Winds are predominately from a northern direction, light to moderate in force with infrequent gale-force winds associated with strong frontal passages.

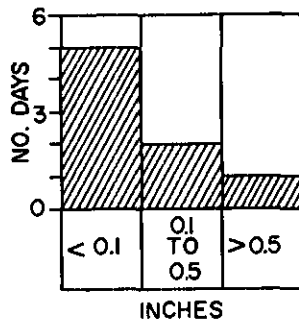
Table I. Overland Operation OBJECTIVE FOUR—February

Temperature (° F.):	February
Mean Maximum.....	45
Mean.....	38
Mean Minimum.....	32
Recorded Extremes.....	64 to 10
Mean Number of Days With:	
Precipitation.....	16
0.1 inch.....	8
0.1 to 0.5 inch.....	5
0.5 inch.....	3
Snowfall.....	5
Snow on ground.....	5
Mean Relative Humidity (%):	
0700 LST.....	85
1400 LST.....	71
1900 LST.....	80

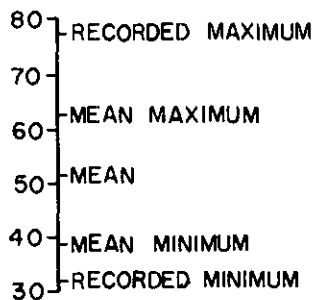
CLIMATIC DATA FOR OBJECTIVE ONE MAY

PRECIPITATION

APPROXIMATE NUMBER OF DAYS
IN WHICH SPECIFIED AMOUNTS
MAY BE EXPECTED TO OCCUR



TEMPERATURE (°F.)



WIND ROSE

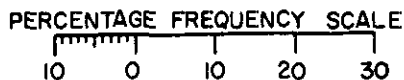
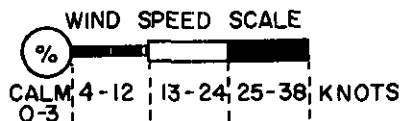
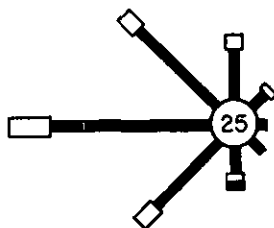


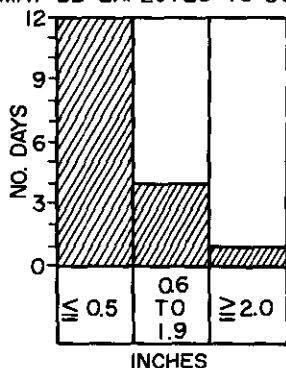
Figure 72. Climatic data for objective one, May.

CLIMATIC DATA FOR OBJECTIVE TWO

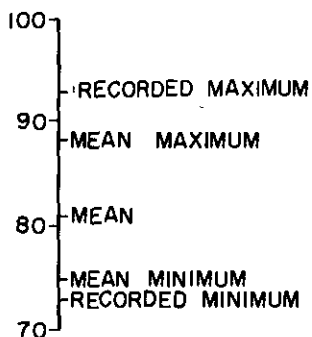
MAY

PRECIPITATION

APPROXIMATE NUMBER OF DAYS
IN WHICH SPECIFIED AMOUNTS
MAY BE EXPECTED TO OCCUR



TEMPERATURE (°F)



WIND ROSE

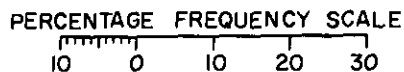
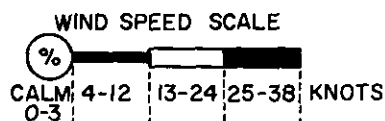
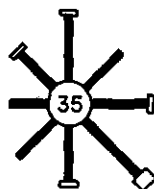
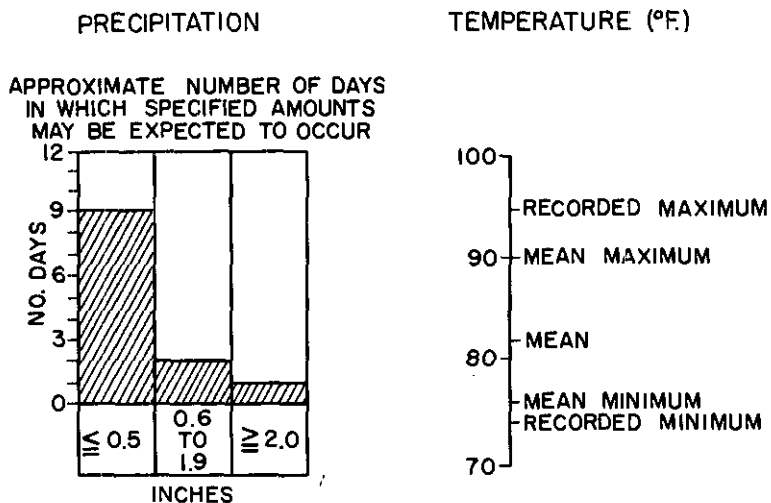


Figure 73. Climatic data for objective two, May.

CLIMATIC DATA FOR OBJECTIVE TWO JUNE



WIND ROSE

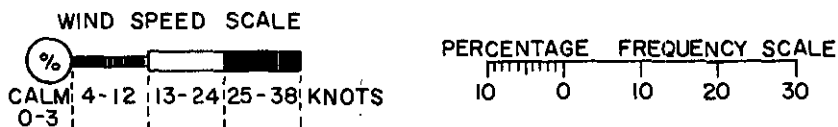
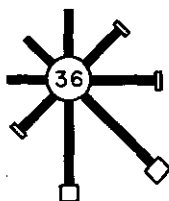


Figure 74. Climatic data for objective two, June.

CLIMATIC DATA FOR OBJECTIVE THREE SEPTEMBER

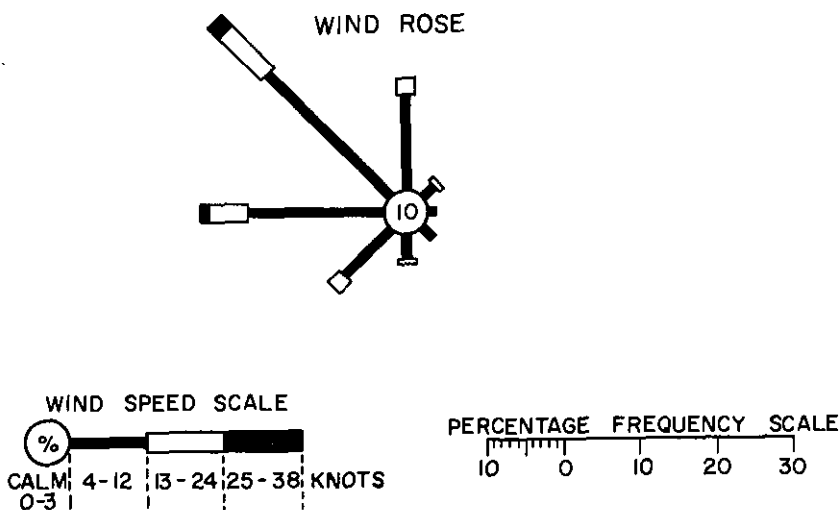
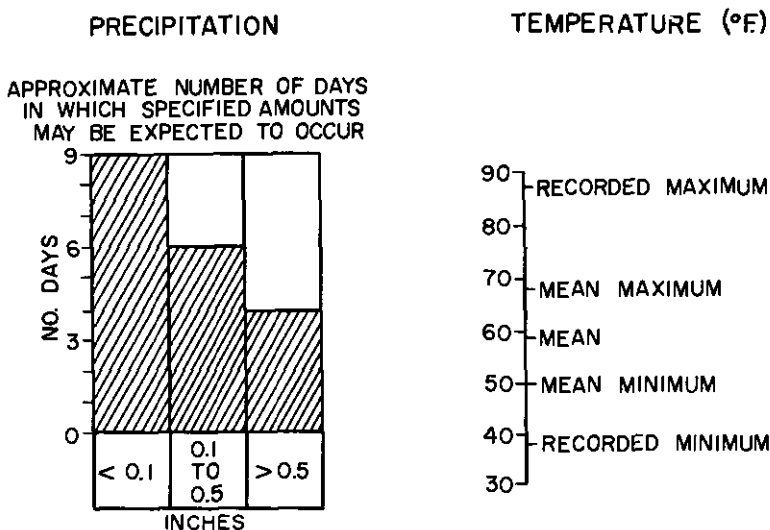


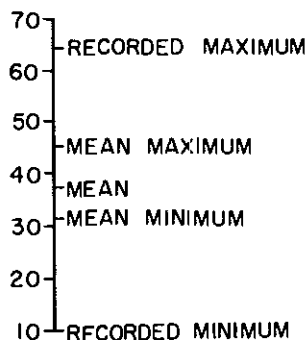
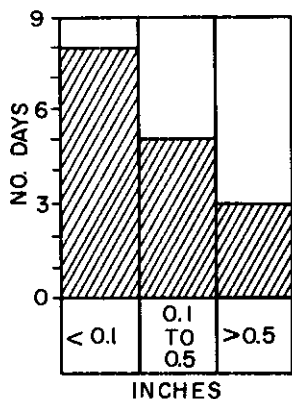
Figure 75. Climatic data for objective three, September.

CLIMATIC DATA FOR OBJECTIVE FOUR FEBRUARY

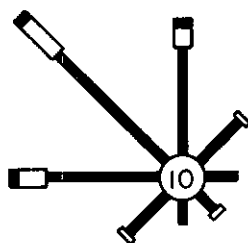
PRECIPITATION

TEMPERATURE (°F.)

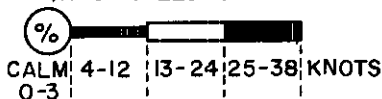
APPROXIMATE NUMBER OF DAYS
IN WHICH SPECIFIED AMOUNTS
MAY BE EXPECTED TO OCCUR



WIND ROSE



WIND SPEED SCALE



PERCENTAGE FREQUENCY SCALE

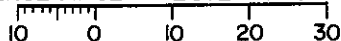
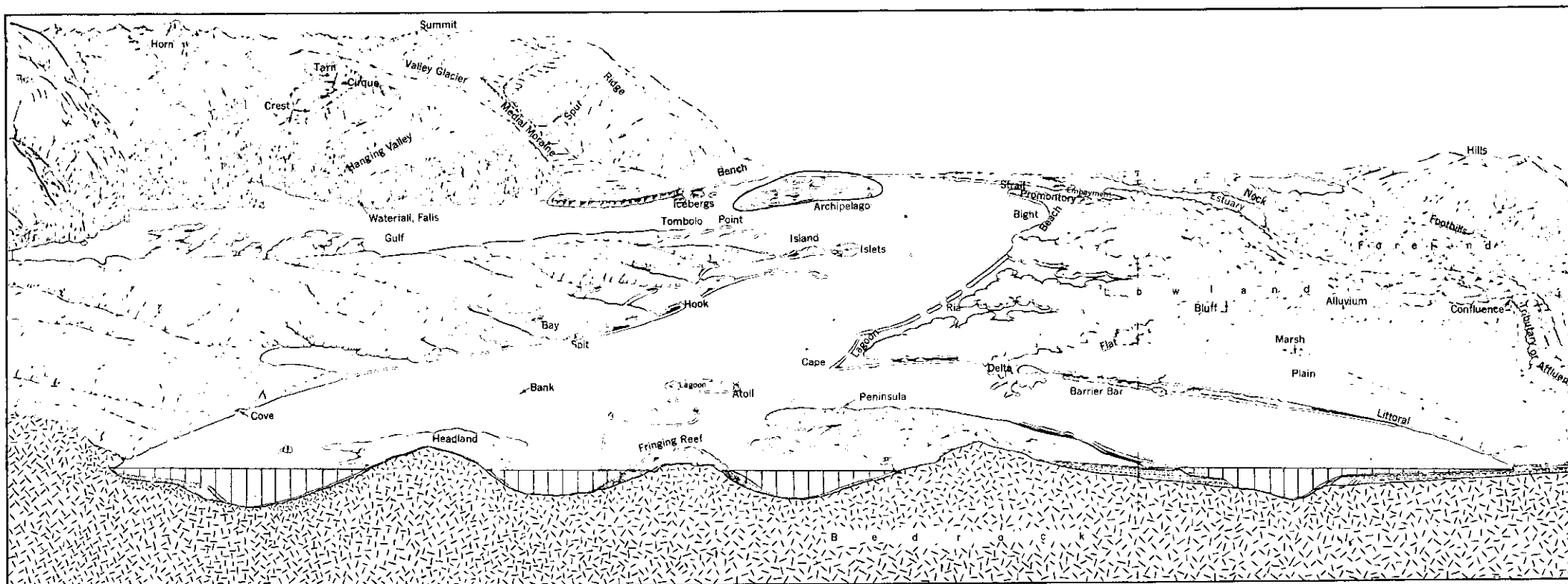


Figure 16. Climatic Data for Objective Four, February.

APPENDIX VI

NATURAL TERRAIN FEATURES

The natural terrain features shown in figure 77 A, B and C, will serve as a guide to producers and users of terrain studies. The definitions of the terms used in these figures have been composed after careful review of source material. In a few cases, where feasible, arbitrary limits have been established to permit users and producers of terrain studies to distinguish between terms that are similar in some respects: e.g., silt and sand, gravel and cobble. Other terms, e.g., brook and creek, plain and plateau, bay and gulf, are of such a nature that they can be distinguished only by general remarks relating one to the other; in these cases, no definitive distinction can be drawn and terrain terminology remains loose; many of these terms have their origin in popular rather than technical usage.



A

Figure 77. Natural Terrain Features.

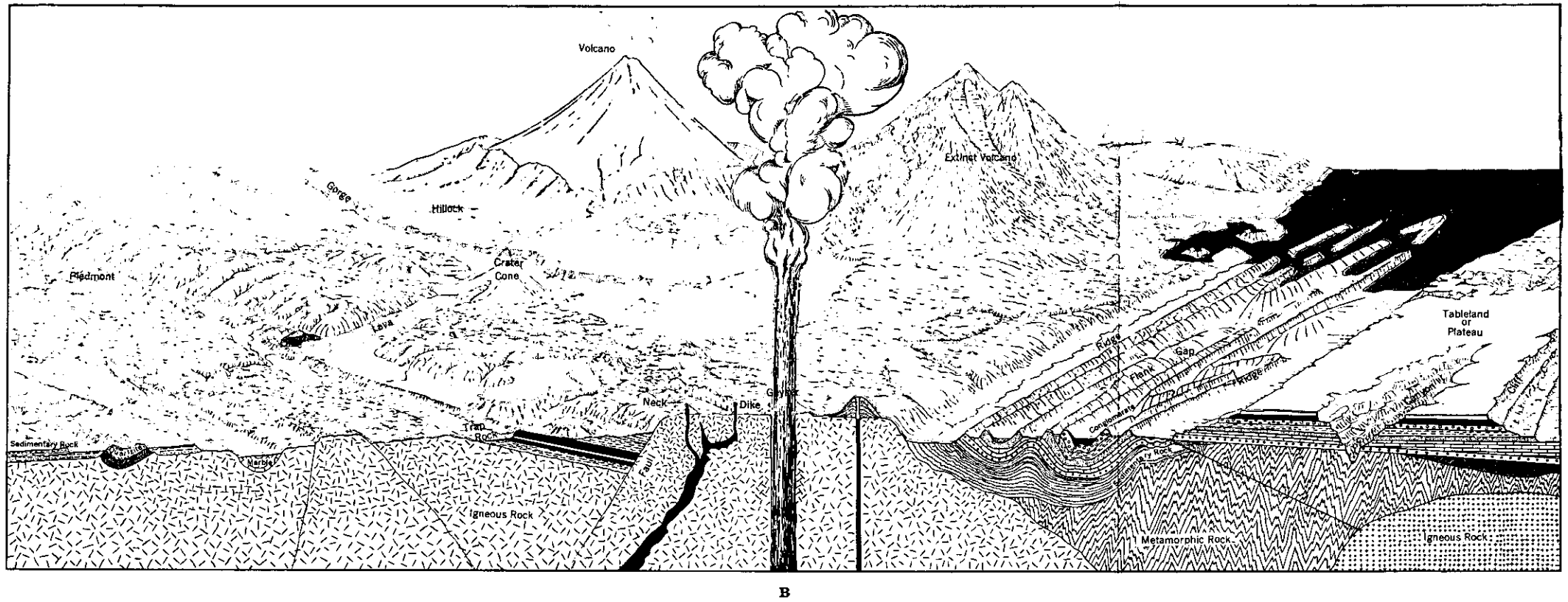
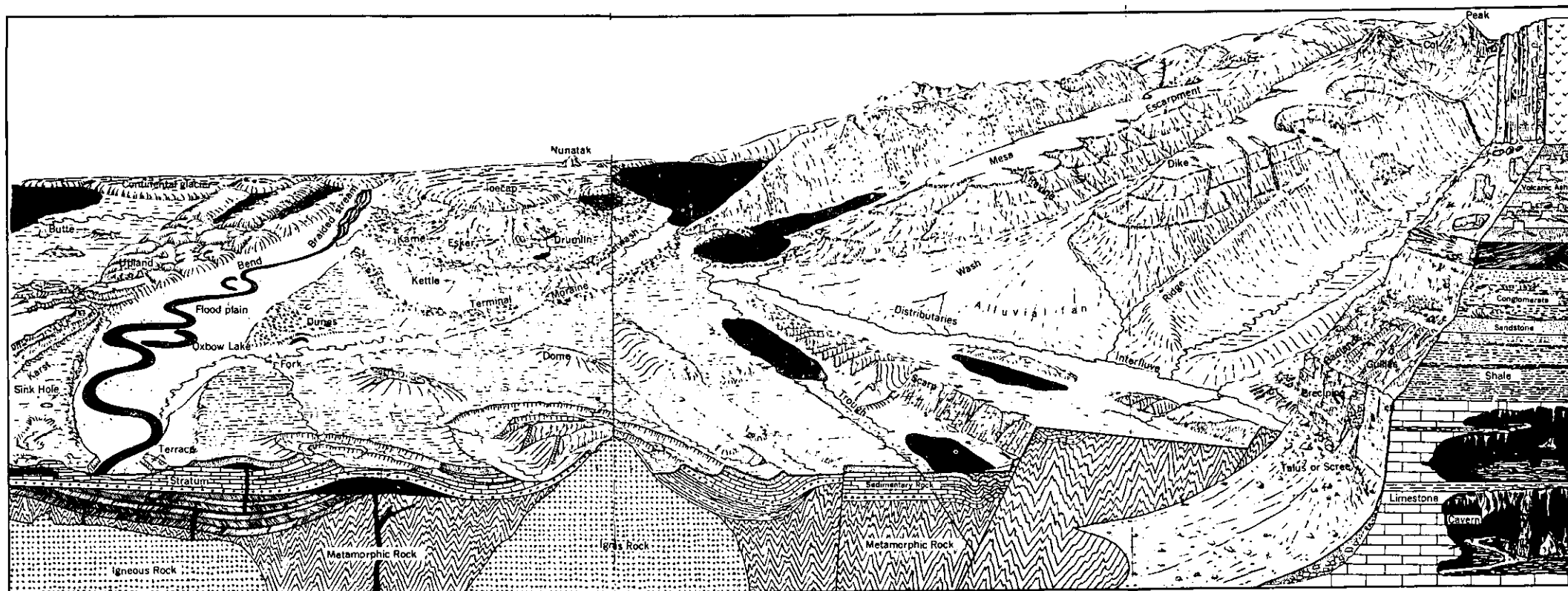


Figure 77.—Continued.



C

Figure 77.—Continued.

GLOSSARY*

Alluvial fan—An accumulation of alluvial materials, formed where streams with a steep gradient have their velocity checked abruptly by flowing onto a gentle slope; generally shaped like an open fan or a segment of a cone.

Alluvium—Gravel, sand, silt, and clay deposited by running water.

Aquifer—A layer of rock or soil, or a zone of fractured rock, that yields or could yield water to wells.

Archipelago—1. A continuous group of islands occupying a broad expanse in a large body of water.

2. A large body of water studded with islands.

Artesian water—Ground water that is under sufficient natural pressure to rise above the level of the water table.

Atoll—A ring shaped coral formation consisting of coral reefs, coral islands, or most commonly both, encircling or nearly encircling a lagoon. The formation commonly is built up by algae as well as by coral animals.

Backshore—1. The usually dry part of a beach which is reached only by the highest tides, or covered by water only during exceptional storms.

2. A narrow strip of relatively level coast bordering the sea.

Bank—1. The continuous sloping margin of a stream or other water body; on a stream, designated left or right bank as it would appear to an observer facing downstream.

2. An elevated submerged tract forming a shallow sector in a sea, lake, or stream; a shoal or shelf.

Bar—A mass of unconsolidated material, either submerged or at the surface, lying across the mouth of a stream, estuary, or bay (bay-mouth bar), or lying parallel to a shore (barrier bar), or a ridge of sand or gravel or both, lying seaward of a shore (offshore bar).

Basin—1. A broad surface depression which is entirely or nearly enclosed by high ground.

2. A broad, nearly enclosed section of a valley.

3. The area drained by a stream or lake; a watershed.

4. Any enclosed surface trough; it may contain water, as a lake or ocean basin.

*These definitions are based upon the simplified standard terminology adopted by the Corps of Engineers for terrain studies. They do not necessarily conform to those employed in geology or the other earth sciences.

5. An area in which the rock layers slope inward from all directions; a structural basin.
- Bay*—A body of water lying in an indentation of sea or lake coast, usually smaller than a gulf.
- Beach cusp*—One of a series of low mounds of beach material separated by crescent-shaped troughs spaced at more or less regular intervals along the foreshore of a beach.
- Bed*—1. The bottom on which a body of water rests.
2. A layer of rock differing from layers above and below, or set off by more or less well marked divisional planes; a layer in a series of stratified (sedimentary) rocks.
- Bench*—1. An elevated, narrow platform of relatively level earth or rock.
2. A terrace or shelf along a body of water, commonly representing its former level.
- Berm*—A nearly horizontal part of a beach or backshore extending landward beyond the normal limit of wave uprush; formed by the deposition of material induced by wave action. Some beaches have several berms, others have none. The crest of the most seaward berm divides the beach into a seaward part, foreshore, and a landward part, backshore.
- Bight*—1. A bend in a coast forming an open bay.
2. The open bay formed by the indentation.
- Bluff*—1. An extended steep, high slope, commonly bordering a stream or other body of water.
2. A steep, high bank of loosely consolidated material.
- Boulder*—A large rock fragment, commonly rounded or otherwise modified in shape while being transported by glacial ice, water, or wind. A boulder is larger than a cobble; 10 inches is arbitrarily suggested as a lower limit for its diameter.
- Brackish (water)*—Slightly salty; intermediate in salt content between fresh water and sea water.
- Braided stream*—A stream flowing in several channels; stream divides and reunites in a pattern resembling the strands of a braid.
- Branch*—1. A small stream that flows into a larger one; a tributary.
2. A stream flowing out of the main channel of another stream and not rejoining it, as on a delta or an alluvial fan; a distributary.
3. A stream flowing out of another and rejoining it; a braid.
- Broadleaf tree*—A tree with broad, flattened leaves, which may be either deciduous or evergreen. Broadleaf trees produce hardwood.
- Brook*—1. A fresh-water stream of relatively small size, commonly in rugged terrain and quick flowing.
2. A tributary of a river or a larger stream.

- Brush*—1. Scrubs, bushes, small trees, or other low vegetation species, growing together either in a woods or in open areas.
2. A thicket of shrubs, bushes, small trees, etc.
- Butte*—An isolated, flat-topped hill or mountain with steep sides, smaller than a mesa; it is generally situated in an arid region.
- Caliche*—1. A calcareous material occurring in a layer or in layers at or near the surface in arid or semiarid areas. It consists of gravel, sand or clay and a cementing material, generally calcium carbonate.
2. A soft horizon of lime accumulation in the soil.
- Canopy*—The overhanging, shading, or sheltering part of a tree or forest.
- Canyon*—A deep, relatively narrow, steep-sided valley, generally with a stream occupying most of its floor.
- Cape*—1. A pronounced irregularity of a coastline projecting into a large body of water.
2. The part of the irregularity projecting farthest into the water.
- Cave*—A sizable underground hollow, generally with a surface entrance.
- Cavern*—A large cave, in places of indeterminate extent.
- Chain*—1. An extended group of more or less parallel features of high relief, including mountains, hills, or plateaus.
2. Any series of related or interconnected natural features.
- Channel*—1. The trench in which a stream normally flows.
2. A relatively narrow stretch of sea between two larger bodies of water; a strait.
3. The deepest part of a stream, bay, or strait through which the main current of water flows.
4. The part of a body of water deep enough to be used for navigation through an area which in places is too shallow.
- Chasm*—A deep, relatively narrow cleft in the earth's surface.
- Chinook*—See foehn.
- Cirque*—A deep steep-walled hollow in a mountain or hill caused by glacial erosion; a snowfield or glacier may still occupy the cirque.
- Cliff*—A high, extremely steep slope, generally of consolidated rock.
- Cobble*—A rock fragment, generally rounded, from 3 to 10 inches in diameter.
- Col*—A low place in a ridge or crestline; commonly the divide separating two valleys, especially if the valleys slope steeply away from the divide; a saddle or gap.
- Cone*—A mountain or hill with a pointed top and shaped like a cone; generally characteristic of peaks of volcanic origin.
- Confluence*—The place where two or more streams unite.
- Conglomerate*—Rock formed by the natural cementing together of rounded pebbles (gravel), cobbles, or boulders.

Continent—One of the grand divisions of land on the globe, usually regarded as six: North America, South America, Europe, Asia, Africa, and Australia.

2. A large, continuous extent of land; a mainland.

Cove—1. A small sheltered inlet in a coast; a small bay.

2. A sheltered recess in hills or mountains.

Cordillera—A large regional grouping of mountain chains.

Creek—1. A fresh-water stream of intermediate size, smaller than a river and larger than a brook.

2. A relatively small tidal inlet or estuary of a coast; generally referred to as a tidal creek.

Crest—1. The ridgeline that crowns an elongated eminence, from which the surface slopes downward in opposite directions.

2. The summit area of an eminence.

Crevasse—1. A relatively deep, narrow fissure, especially on an ice or snow surface. On an icecap or glacier, the fissure may be hidden by a shallow cover of snow or ice.

2. A break in a levee or other stream embankment.

Cuestaform plain—Long, low ridges alternating with lowlands in bands several miles wide and many miles long generally parallel to the coast.

Debris—Any accumulation of loose material resulting from the decay and disintegration of rocks. It consists of rock fragments, earth, and sometimes organic matter. Debris may occur where it was formed, or where it was transported by water or ice.

Defile—A narrow, natural passageway through difficult terrain, especially mountainous areas.

Delta—A low, nearly level, alluvial plain situated at the mouth of a stream; generally triangular in shape and crossed by streams branching from the main channel (distributaries). A delta is built by the sediments carried by a stream into another body of water, generally a sea or lake, with weak waves and currents.

Dendritic—Treelike arrangement drainage pattern found usually in area underlain by homogeneous rock.

Depression—A hollow completely enclosed by higher ground and having no surface drainage outlet. Water is lost either by going underground or by evaporation.

Distributary—A branch that leaves the main channel of a stream and does not rejoin it. Distributaries usually are associated with deltas or alluvial fans.

Drift—Any rock material, such as boulders, gravel, sand, or clay, transported by a glacier and deposited by or from the ice by water derived from the melting ice. Also called *glacial drift*.

Duff—Plant litter in various stages of decomposition lying on the soil surface, usually in a forest.

- Eddy*—A current of water running contrary to the main current, especially one moving in a circle; a whirlpool.
- Embayment*—1. An open indentation of a shoreline.
2. The body of water lying in the indentation; an open bay.
- Eminence*—1. An elevated area of any size, shape, or height.
2. The high point of an elevated feature.
- Escarpment*—A long cliff or steep slope of consolidated material separating flat or gently sloping land lying at different levels.
- Esker*—A long, narrow, commonly winding ridge of gravel and sand deposited by a stream that formerly flowed between banks of a glacier.
- Estuary*—That portion of a stream influenced by the tide of the body of water into which it flows. Estuaries occur in coastal areas that have sunk with respect to sea level; parts of stream channels are thereby depressed below sea level, or “drowned.”
- Falls*—A precipitous descent of water in a stream, or from a spring or lake.
- Fault*—A fracture or fracture zone in the earth’s crust along which there has been displacement (vertical or horizontal) of the two sides relative to one another parallel to the fracture. The displacement may be a few inches or thousands of feet.
- Fjord (fjord)*—A long, narrow arm of the sea enclosed by steep rocky slopes. The water is generally deep but rock or earth sills are common at the bottom. Fjords occur chiefly in areas of present or former glaciers.
- Flash flood*—A sudden, swift torrent overflowing a stream channel, usually as a result of very heavy rains in areas having steep slopes.
- Flat*—1. A nearly level surface; a plain.
2. A nearly level tract at the bottom of a narrow, steep-sided valley.
3. A relatively level tract lying at a little depth below water or alternatively covered and uncovered by a body of water; a shallow; a shoal.
- Floe*—A low, floating ice mass formed in a large body of water.
- Foehn*—A relatively warm, dry wind which blows down a mountain-side when a cyclonic storm causes air to cross the range from the opposite side of the divide. Called a chinook in U.S. and Canada.
- Ford*—A site in a stream or other water that can be waded by man or traversed by land vehicle such as car, truck, or tank. The water body at a ford is shallow, and has low velocity and a firm, level and not too bouldery bottom.
- Foreland*—1. A mass of high ground that projects into a large body of water such as a sea; a promontory or headland.
2. The land adjoining a highland and physiographically related to it.

Foreshore—The part of the shore along a coast which is ordinarily traversed by the uprush and backwash of the waves as the tides rise and fall; i.e., between the crest of the most seaward berm and the normal low water mark.

Fork—1. The place where one stream flows into another; a confluence.

2. The smaller of the streams that unite; in places, each of the uniting streams when the resulting stream is much larger than either of them.

3. The land lying in the angle made by the junction of streams.

Gallery forest—A relatively long and narrow strip of dense tree growth along a stream or lake; tree crowns may form a canopy over a stream; commonly in an area that does not have trees except along a water body.

Gap—1. A passage at a relatively low elevation through a high ridge or mountainous area.

2. Any significant break in the high elevation of a mountain or hill ridge or range.

Geyser—A spring which intermittently ejects jets of heated water and steam to a considerable height. Its action results from the contact of percolating ground water with heated subterranean rock.

Gorge—A deep, narrow, steep-sided valley, commonly with a stream occupying most of its floor.

Grove (uncultivated)—A small area covered by a dense growth of trees, usually with little undergrowth and surrounded by open land.

Gulf—A part of a large body of water lying in an indentation of a coast; usually larger than a bay.

Gully—A small surface trench excavated by running water, commonly intermittent. Gullies most commonly form on a bare slope.

Hanging valley—A valley the floor of which is notably higher than the valley or shore to which it leads; most common in areas that have been glaciated. The stream draining a hanging valley becomes a cascade or fall where the valley ends.

Head—1. The source or upper part of a stream or other enclosed water body.

2. The upper part of a sloping feature such as a valley.

3. A headland.

Headland—1. An irregularity of a coastline, especially high ground, projecting into a large body of water.

2. The high ground flanking an enclosed water body, such as a cove; a promontory.

Headwater—The upper part of a stream, near the source.

Hedgerow—A linear thicket of bushes, commonly with some trees, left between two fields of cleared land, or planted in order to separate fields. Commonly a ridge a few feet high, bordered by a ditch

on one or both sides. Especially common in parts of England and France.

Highland—A relatively large area of elevated or mountainous land standing prominently above adjoining low areas.

Hollow—1. A tract of low ground fringed by hills or mountains.

2. A small, sheltered valley or basin in rugged terrain.

Hydrology—The science treating water, its properties, phenomena, and distribution, especially with reference to underground water.

Hydrostatic pressure—The pressure exerted by standing water.

Ice-fog—Fog composed of ice crystals.

Igneous rock—Rock formed by cooling and solidification from a molten or partly molten state; may be coarse grained (granite if light colored, gabbro if dark), fine grained (rhyolite or basalt), or glassy (obsidian and other volcanic glass), or may vary notably in grain size (porphyry).

Inlet—1. The body of water lying within a narrow recess in a coast-line.

2. A narrow channel connecting two broader water bodies, especially in coastal areas.

3. A narrow channel between islands.

Inversion—The condition which exists in the atmosphere when the temperature increases rather than decreases with height through a layer of air.

Interfluvium—The area lying between two streams.

Intermontane plateau—Plateau surrounded or nearly surrounded by mountains.

Kame—A conical hillock or short irregular ridge built of sand and gravel deposits accumulated in contact with glacier ice.

Karst plain—Plain with numerous depressions caused by solvent action of underground water.

Katabatic winds—Those caused by the descent of downslope air through the action of gravity.

Knob—A rounded hill or mountain, especially an isolated one.

Knoll—A small, low, eminence, generally rounded; a hillock or mound.

Lagoon—1. A shallow body of water partly or completely separated from the sea by a narrow strip of land; the water is generally salty.

2. A shallow body of water enclosed or nearly enclosed by coral reefs, or islands, as in an atoll.

Ledge—1. A narrow, nearly level surface, especially one projecting from a steep rocky slope.

2. A reef, especially one near the shore.

Littoral—1. The land immediately adjoining a sea or lake.

2. The land along a coast lying between high and low tide levels.

Loam—A soil containing nearly equal proportions of sand, silt, and clay; may also contain minor amounts of humus, pebbles, or boulders.

Loess—Windblown particles of silt.

Macadam—Roadway constructed by compacting into a solid mass a layer of small broken stones on a convex well-drained earth road bed.

Meander—One of a series of arc-shaped bends of stream, generally occurring where a stream has a low gradient.

Mesa—A flat-topped, steep-sided hill or mountain of smaller extent than a plateau; generally situated in an arid region. Although a mesa is generally an isolated feature, the term also is applied to any broad, flat, elevated surface which is bounded on at least one side by a steep slope.

Mistral—A violent, cold, dry northerly wind characteristic of the Mediterranean provinces of France.

Monadnock—A hill or mountain of resistant rock surrounded by a peneplane.

Oasis—A fertile green spot in a desert, resulting from springs or the presence of ground water near the surface.

Outcrop—The part of a stratum or mass of rock that appears at the surface.

Overburden—1. Loose soil, sand, gravel, etc., that lies above bedrock.

2. Material, consolidated, or unconsolidated, that must be removed to gain access to useful deposits such as coal, ore or gravel.

Oxbow lake—A crescent-shaped water body that was formerly part of a stream meander. When the stream cuts a new shorter channel across the neck of the meander, the ends of the meander become silted up, separating the oxbow lake from the stream.

Peneplane—A land surface worn down by erosion nearly to a plain.

Peninsula—A relatively large tract of land projecting from a land mass into a sea or lake and nearly surrounded by water.

Permeability—Capacity of a material to transmit water.

Piedmont—An area lying at the foot of a mountain area.

Pinnacle—1. A spire-shaped mass at the summit of a mountain or hill.

2. A hill or mountain with a pointed summit.

3. A small, isolated spire of rock or coral, either submerged or awash, dangerous to navigation.

Plateau—An elevated tract of land, a tableland.

Pond—A body of water occupying a small surface depression; a small lake.

Precipice—A very steep face of any relatively high eminence; it is generally a bare rock slope, and may be vertical or even overhanging.

- Promontory*—High coastal land projecting into a sea or lake, producing an irregular coastline; a headland or high cape.
- Quicksand*—Sand in a semisuspended state in water. Quicksand is shifting or semiliquid, and is incapable of supporting a load.
- Radiation fog*—Fog resulting from the radiational cooling of air near the surface of the ground on calm, clear nights.
- Rapid*—A part of a stream where the current moves with greater than normal swiftness, but without actual waterfall. The stream has a higher gradient in this sector and generally flows through rocks or other obstructions.
- Ravine*—A deep, relatively narrow, steep-sided valley, commonly with a stream on its floor; larger than a gully but smaller than a canyon.
- Saddle*—1. A low place on a ridge or crestline; commonly at the upper ends of two valley, which extend perpendicularly from it in opposite directions.
2. A gap or pass.
- Savanna*—A treeless plain; an open level region.
- Scarp*—1. A relatively straight, steep slope separating land lying at different levels; generally the margin of plateaus, mesas, terraces, benches, etc.
2. A steep slope formed by faulting.
3. A low, nearly vertical slope along a beach formed by wave erosion.
- Scree*—1. A sloping heap of coarse rock waste at the base of a steep, rocky slope; talus.
2. A sheet of coarse debris mantling a hillside or mountain slope.
- Spit*—1. A small, low tongue of land projecting into a body of water, usually the sea; generally sandy.
2. A long, narrow shoal or reef extending from the shore.
- Stand*—1. A growth of trees or other plants; generally expressed with regard to distribution or number in a given area.
2. In a forest, the trees collectively, with more or less uniformity of composition or age.
- Steppe*—A large tract of arid land, generally level and without forests. Used chiefly with reference to southeastern Europe and Asia, in regions of extreme temperature range and loose soil.
- Stratum*—A bed or layer of rock material. It is separated from adjacent strata by surfaces of erosion, nondeposition, or abrupt change in character of the rock.
- Summit*—The apex or upper sector of a peak or ridge.
- Tableland*—A broad, nearly level elevated area such as a mesa or plateau.
- Talus*—Rock debris accumulated at the base of a cliff or slope.
- Tarn*—A small lake in a rocky basin of mountainous or hilly terrain, commonly in a cirque.

Terrace—A relatively narrow plain from which the surface descends on one side and ascends on the other; a bench or ledge. It commonly borders a stream, lake or sea, representing a former water level.

Timberline—1. The elevational limit above which there are no trees or only a few scattered trees. Also known as *treeline*.

2. The poleward limit of trees.

Tributary—A stream which flows into a larger stream or into a lake.

Tundra—A level or undulating treeless plain of the northern Arctic region.

Upland—1. A relatively large area of elevated land standing prominently above adjoining low areas.

2. Elevated ground above the low areas along streams.

Wadi—1. A stream valley in an arid area; it is dry most of the year and is generally steep-sided and bouldery.

2. The intermittent stream in such a valley.

Water gap—A pass in a ridge through which a stream flows.

Watershed—1. The area drained by a stream or lake, including the sections drained by its tributaries.

2. The boundary separating the natural drainage which flows into different catchment basins; a divide or water parting.

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By Order of *Wilber M. Brucker*, Secretary of the Army:

L. L. LEMNITZER,
General, United States Army,
Chief of Staff.

Official:

R. V. LEE,
Major General, United States Army,
The Adjutant General.

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